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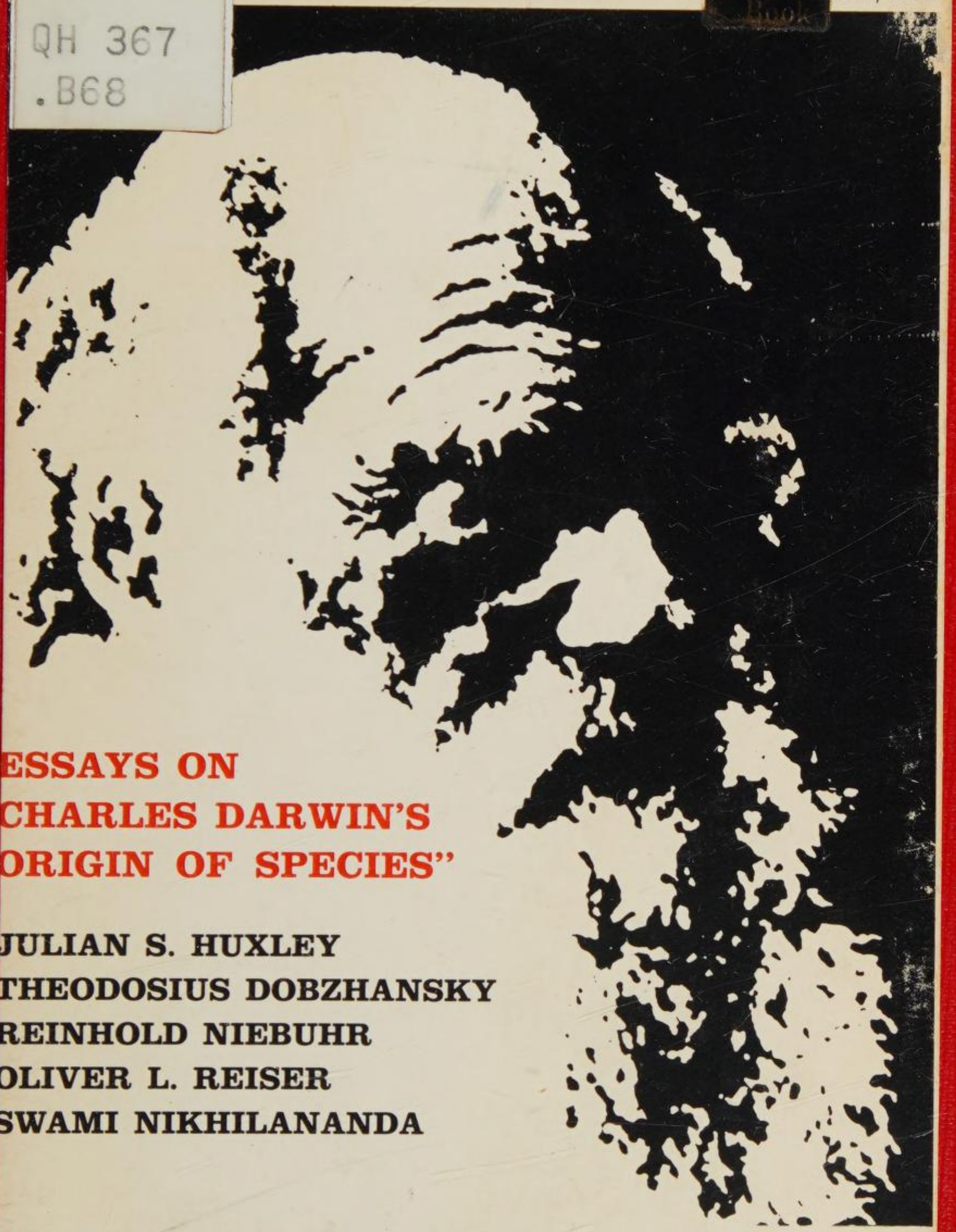

ESSAYS ON CHARLES DARWIN'S "ORIGIN OF SPECIES"

JULIAN S. HUXLEY
THEODOSIUS DOBZHANSKY
REINHOLD NIEBUHR
OLIVER L. REISER
SWAMI NIKHILANANDA

A Book That Shook the World

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Anniversary Essays on Charles Darwin's *Origin of Species*

Julian S. Huxley

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Reinhold Niebuhr

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PREFACE

A CENTURY AGO, 1858, Charles Darwin and Alfred Russel Wallace jointly announced to the Linnean Society of London their independent discovery of natural selection as the method of evolution. And the following year, in 1859, Charles Darwin published his famous classic, *Origin of Species*.

Countries over the world today are celebrating the centenary of these events and honoring Darwin and his book as the beginning of new biological thought.

The University of Pittsburgh Press publishes the five essays in this book as its share in this important centenary celebration.

Each essay has been written by a specialist in an individual field of interest and study affected by Darwin's book. Each is a man of distinction in today's world of research and thought. Each writes to show the effect of the publication of Darwin's *Origin of Species* on his own field.

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DARWIN AND THE IDEA OF EVOLUTION

Julian S. Huxley

CHARLES DARWIN is and will always remain one of the pre-eminent figures in human history. He rendered evolution inescapable as a fact, comprehensible as a process, all-embracing as a concept. After Darwin it became necessary to think of the phenomenal world in terms of process, not merely in terms of mechanisms, and eventually to grasp that the whole of reality is a single process of evolution.

Let us, however, not allow Darwin's pre-eminence to dim the memory of Alfred Russel Wallace. You will recall that the idea of natural selection as the method by which adaptations could be produced and species were transformed flashed into his fever-stimulated mind as he lay in bed on the island of Ternate in the Moluccas. On that same day he thought out his theory and made a first draft of it; wrote it out in full during the next two days and sent it off to Darwin, all unknowing that Darwin himself had hit on the same idea some twenty years previously and was still laboriously assembling facts to support it and working out all its implications.

This independent discovery of a master principle was a notable intellectual feat. But Wallace's importance for biology actually resides in the fact that his communication of the theory to Darwin forced the older man to overcome his extraordinary diffidence over publishing his results and stimulated the appearance of the *Origin of Species* in the subsequent year, in place of the "very big" book that he was planning. We must remember that fifteen years previously he had written up his subject in an *Essay*, though an essay of over 200 pages - but had consistently refused to heed the pleas of Lyell and Hooker that he should give his conclusions to the world until he felt secure in his evidence. If it had not been for Wallace, Darwin might have continued his accumulation of facts and arguments for another fifteen years, the "very big book" could have missed the psychological moment, and its sheer bulk might well have rendered it unreadable.

In passing let me note the curious fact that Darwin did not use the term *evolution* in the earlier editions of the *Origin of Species*,

even though Herbert Spencer had employed it, essentially in its modern sense, some years before 1859. Historically the fact is that *evolution* had previously been used in the sense of the unfolding of a miniature preformed set of organs and characters. This was notably so in the field of embryology and individual development, where *evolution* in this sense had been opposed to what was soon shown to be the correct concept of *epigenesis*, implying the orderly appearance of quite new properties during development. Biological evolution as Darwin saw it and as we see it to-day is clearly epigenetic. Perhaps it was the echo of the earlier usage which made Darwin chary of using the word *evolution*, and also led many French and German biologists to prefer the terms *transformisme* and *abstammungslehre*, respectively.

We may now consider briefly how Darwin's work has stood the test of time. His primary achievement lay in providing evidence for evolution, in demonstrating that the observable phenomena of biology made it impossible to believe in the stability of species in time, in a single original creation or in serial creation in relation with a succession of cataclysms; on the contrary, they indicated a slow transformation of types taking place over very long periods. He was the first to establish the fact of evolution on a firm basis. Here all later work has provided overwhelming confirmation. We can still marvel at the range of the evidence he assembled - from geographical distribution, from variation in domesticated and wild species, from embryology, from taxonomy, from the facts of adaptation, from "living fossils" such as lungfish and linking types such as Archaeopteryx, from the succession of types revealed by palaeontology, from comparative anatomy and comparative behavior. The main gap in his evidence was the absence of fossil series showing the gradual specialization of type; paleontological discovery has now satisfactorily filled that gap. In all other fields, later research has merely rounded out and amplified his evidence.

His other major achievement was the discovery of the principle of natural selection, which made the brute fact of evolution scientifically comprehensible. This has had a much more chequered history. There was a period when the principle was under heavy and indeed bitter attack, from the Lamarckians and the vitalists on the one hand, from the strict orthogeneticists and the mutationists on the other. Natural selection was attacked by some as being too teleological; and by others because it depended solely on "chance," and therefore was not teleological enough to produce the apparently purposeful characters that everywhere confront the biologist. At one period it was maintained that though natural selection would have a negative effect, in pruning the species of deleterious variations, it could not have a positive effect and bring about directional transformation. And, it was urged, natural selection had never been experimentally proved to be operative.

All these objections have now been met. We can not only point to cases where natural selection is operative in producing transformations or in maintaining adaptations, but can often measure its strength quantitatively. We know that it can produce positive as well as negative effects, and is the only agency which can bring about change (evolutionary transformation) in certain circumstances, no change in others. We have elaborate mathematical theories demonstrating how selection will operate in different circumstances. And we have proved that Lamarckian inheritance or inherent vital urges to change do not exist.

In view of the lack of scientific knowledge at the time when Darwin wrote, his ideas about the mechanisms of heredity and variation could of course only be speculative, and his theory of pangenesis has now turned out to be erroneous. However, it is interesting to find that the discoveries of modern genetics have actually strengthened his evolutionary conclusions. His central theory of natural selection is now finally and firmly established, though in somewhat modified form. His idea of the struggle for existence as he formulated it, which involved the all-or-nothing alternatives of survival or death, has been replaced by that of the differential survival of variants. New favorable combinations of small mutations will enjoy a slight advantage, so that old alleles in the hereditary constitution will gradually be replaced by new, and the average of the type will change slowly over the generations.

The discoveries of genetics have got rid of Darwin's greatest difficulty. He (in common with many others, including the biometricians half a century later) thought that complete blending of the two parental types would occur in heredity, so that any new variation would tend to be diluted by crossing in each generation. This involved the common confusion (not finally cleared up until well into the present century) between phenotypic characters on the one hand and genetic determinants or genes on the other. Characters show blending: genes do not. We know that inheritable variations are due to mutations, in other words to self-perpetuating changes of definite extent in the self-reproducing material units of the genetic constitution, the genes; and that blending of hereditary material never occurs. Furthermore, many mutations are recessive, and can be transmitted in a latent heterozygous state. Recurrent mutation is frequent, and keeps up the supply of many mutants which might otherwise be eliminated. Heritable variations of the genetic outfit may thus persist indefinitely (unless too disadvantageous when allowed to express themselves in phenotypic effects), and a large supply of potential variance can be kept in store in the constitution, ready to be utilized and to become property of the species should conditions demand it.

In fact, as R. A. Fisher definitively showed in 1930 in his book,

The Genetical Basis of Natural Selection, a particulate mechanism of heredity, as demonstrated by the later development of Mendelism, provides firm support for Darwin's theory. Only on a particulate basis will natural selection be effective.

Darwin deduced that natural selection would automatically lead to "the improvement of most organisms in relation to their conditions of life," as he characteristically phrased it—to better detailed adaptations, to increased efficiency of particular biological functions, such as locomotion or self-regulation, and to improvement in the pattern of general organization. This conclusion has been abundantly confirmed. Adaptation is omnipresent in living organisms, and higher and more efficient types do appear in the course of evolution.

He also concluded that natural selection would automatically promote the variety of organisms by causing species to diverge in their habits and capacities in relation to their different conditions of life. Greater variety is a biological advantage because it spells a fuller exploitation of the resources of the environment. Here again later research has amply confirmed Darwin. Natural selection, when combined with isolation, does cause local populations to diverge from each other (the wrens of St. Kilda have evolved into a distinct subspecies since the end of the Ice Age); and changed conditions may bring about rapid local evolution (the moths of industrial areas have turned black and become more resistant in less than a century).

He anticipated modern evolutionary genetics by deducing that wide-ranging and abundant species would be more variable, and would have a high capacity for further evolutionary change.

Darwin's theory of sexual selection was intended to account for the evolution of secondary sexual characters. When actual fighting for the possession of mates occurred, he argued, it would promote male strength and size and the development of male weapons; when, on the contrary, display instead of physical violence was the rule, the females would tend to select the males with the most brilliant colours and the most exciting displays. Darwin himself regarded sexual selection as an important supplement to natural selection, though he erroneously imagined that it would be less rigorous and therefore less effective. New facts have led to considerable modifications in the theory. Thus, many male weapons (such as deer antlers) serve solely as threat or bluff characters—mere symbols of strength; and many male displays are expressions of hostility to rivals, not of attraction to a potential mate. Further, actual female choice of one male rather than another, though it does occur in some polygamous-promiscuous birds, is rare, and male display usually serves only to stimulate the female's readyness to mate. Furthermore, Darwin was ignorant of the fact that mutual ceremonies, displaying striking plumage

developed by both sexes in the breeding season, are widespread among birds, and can only be understood as constituting an emotional bond between the mated pair, as well as providing a stimulus to actual coition.

However, an important core of validity remains. Selection does operate to produce striking secondary sexual characters, but it is better called *intrasexual* than simply sexual. There is competition for reproductive success between the males of the same species, and selection in such a case may produce results which are of no advantage to the species in the day-to-day struggle for existence or in competition with other species, and indeed (as with the exaggerated wing-feathers of the male Argus Pheasant) may actually be disadvantageous. Further, though female choice between alternative males is rare, female awareness is the major operative factor in determining the evolution of epigamic display characters: they are *allaesthetic*. Thus, intrasexual intraspecific selection is supplementary to ordinary natural selection, and produces results of a new and different type.

Two other facets of Darwin's vast work deserve mention for their general importance—his treatment of the evolution of man and of the evolution of mind. In the *Origin*, in 1859, Darwin contented himself by saying merely that, through the acceptance of the idea of evolution, "light will be thrown on the origin of man and his history." But twelve years later he devoted half of *The Descent of Man* to the problem, assembling a large body of evidence to demonstrate that our species must have originated from an anthropoid ancestor. This conclusion, too, has been amply confirmed. The only major modifications brought about by later discovery are, first, that the length of time since the hominid stock diverged from the anthropoid is greater than Darwin supposed, and secondly, that our immediate prehuman ancestors were less like any existing great ape, and more resembled the Australopithecines of Southern Africa. He fully appreciated the unique character of man, notably his capacity to transmit the fruits of experience cumulatively by means of language, and so opened the door to recognition of the wholly novel character of human or cultural evolution, and to the intensive study of its processes and peculiarities.

Nor did Darwin shrink from applying evolutionary ideas to the development of "the mental qualities of animals," as he writes in the *Origin*. He never shirked the implications of evolution as regards mind, and never pretended that "mental qualities" did not exist in animals, nor tried to disguise their reality by a purely behaviourist terminology. With his book on *The Expression of the Emotions in Man and Animals* (1872) he may be said to have founded the science of comparative psychology and behaviour, or ethology as it is now called, and showed conclusively that

emotions, their expression and their recognition by others, must have evolved as surely as physical characteristics. And in *The Descent of Man* he had insisted that even the most striking and apparently unique mental and moral characteristics of man must have originated from mammalian forerunners by the operation of natural selection.

These general conclusions, too, have been beautifully established by the vast body of later research in this field. Indeed, though at one time the specialists shied away from concepts such as instinct and from the use of terms with a subjective connotation, such as emotion or intelligence, recent workers are tending to return to Darwin's robust and comprehensive approach.

The remainder of Darwin's work is more specialized—on the fertilization of orchids, on insectivorous plants, on the movements of plants, on heterostyly and on cross- and self-fertilization, on the formation of coral islands, and on the role of earthworms in nature, not to mention the four-volume monographic treatment of living and fossil barnacles, and of course a large number of papers and notes in scientific journals.

However, virtually all of it, with the exception of that on earthworms, represents an expansion of studies already undertaken before 1859, and incorporated in the argument of the *Origin*. The biologist of to-day, accustomed to our modern specialization, cannot but feel overwhelmed by the range and sheer magnitude of Darwin's work. His books alone (and everyone knows the greater labour involved in writing a book as against publishing an equivalent volume of print in spearate papers) total well over 8 thousand pages: and contain, on a very rough estimate, about 3 million words. He ranged over all the sciences of nature - geology, botany and zoology—and dealt with problems of heredity, embryology, growth, sex, behaviour, adaptation, extinction, geological time, paleontological succession, and the interrelations of organisms. Indeed he may properly be said to have initiated the scientific study of the fields that we now call ecology and ethology.

His influence, of course, extended into many other fields. The evolutionary approach was adopted in linguistics, astronomy, comparative religion, geophysics, archaeology, and many other subjects; and recently the idea has begun to dawn that it is profitable and indeed necessary to regard all reality *sub specie evolutionis*, to think of the entire cosmos as a single stupendous process of evolution, though with differentiated component sectors or phases.

Alfred Russel Wallace himself called Darwin the Newton of biology. The appellation is deserved. Newton introduced order and unity into the physical world, Darwin into the biological world. And, just as Newtonian regularities spilled over into biology, so the evolutionary orderliness discovered by Darwin spilled over into the inorganic realm on the one hand, the human realm on the

other. It is not only for the profundity but for the universality of his ideas that we acknowledge Darwin's pre-eminence in the history of human thought.

Darwin's essential achievement was to establish the idea of evolution as a natural process. It remains for me to say something of the significance of the evolutionary idea in present-day thought.

To begin with, if evolution is accepted as a fact, much of the *theological* framework of the world's major religions is destroyed, or is conveniently (but to my mind disingenuously) represented as significant myth.

Here Darwin merely extended the effect of Newton's work into the realm of life. Before Newton it appeared necessary to Christian theologians to postulate a Divine Being to guide the planets in their courses: after Newton, this was seen to be unnecessary and indeed impossible. The universe came to be regarded as a gigantic clockwork mechanism, constructed and set going once for all by God, but then continuing automatically on its course. Miracles in the theological sense became a scientific impossibility: when not the product of ignorant credulity, they turned out to be unusual occurrences or unexplained basic properties of nature—miracles in the etymological sense of things to be wondered at, but not due to Divine intervention or interference.

After Darwin, a similar naturalism was introduced into biology. The idea of creation (including the Cuvierian version of it which postulated a number of successive and different creations, separated by a series of cataclysms) had to be given up in favour of the gradual transformation, diversification, and improvement of one (or a few) extremely simple ancestral forms. And eventually it came to be accepted that ancestral life had not been created: it must have originated from non-living matter at some stage in our planet's history.

Nor could it be supposed that any supernatural agency was needed to guide or interfere with the detailed or general course of evolution: that too is determined by simple natural causes. The apparent purposefulness of biological mechanisms (and, we can now say, evolutionary trends) turns out not to demand conscious purpose by a Divine artificer. The purposefulness is only apparent, and has been brought into existence by the blind and automatic forces of natural selection. Darwin himself stressed that if any case occured where a character of one organism was solely of use to another, he would have to abandon the idea of natural selection; and G. G. Simpson, in *The Meaning of Evolution*, points out that natural selection can never envisage or anticipate future consequences; so that evolution proceeds by a series of improvisations, and the plans of organs (e.g. the eye) are often far from embodying an ideal design.

Indeed, Paley's argument from design now works in reverse. The more remarkable an adaptation is (like the woodpecker's tongue or the bees' communication system), the better it demonstrates the extraordinary efficiency of natural selection. We can (or at least we should) no longer ask what is the use of a mosquito or a tapeworm. It is there because it can survive in certain ecological conditions.

Then, as astronomy has expanded our space-scale, evolution has expanded our time-scale. In place of the recurrent cycles of Hinduism or the few thousand years of Judaeo-Christian theology, and in spite of the grudging estimates of nineteenth century physics, the past of life has been steadily increased by science until it now exceeds the staggering figure of two and one-half billion years. And in place of an imminent Last Judgment, life on this planet (barring some improbable cosmic catastrophe) can envisage at least an equal span of evolutionary time in the future.

Our new knowledge of the mechanism of heredity and variation is enlarging our ideas of the power of artificial selection to extend the work of natural selection. By radiation, we are now artificially producing mutations in crop-plants where the range of variation is low, and then selecting and recombining the few favourable ones to make new breeds. By these and other methods we are doing in a few decades what it took natural selection millions of years to effect—extending the range of species into previously prohibited habitats. Artificial insemination could do something similar for animals, and is opening up the prospect of a practicable system of Eugenics, as H. J. Muller stressed in his book, *Out of the Night*.

The example of industrial melanism in moths, to which I referred earlier, deserves fuller treatment as showing how biologists are tackling the problems of selection on neo-Darwinian lines, with a Mendelian basis for heredity and variation. Within the past eighty years moths of many different species have turned black in industrial areas, but not in the open country. Research has already shown that this is due, not to any direct effect of smoke or chemicals, but to the natural selection of black types. Black types crop up as rare dominant mutants in all the moths, and are hardier and more resistant than the normals (recessive blacks also appear, but do not show increased resistance). But the normals resemble the bark on which they rest by day, and the advantage conferred by this protective resemblance outweighs their lesser hardiness. However, in industrial areas the trees were darker coloured, and there were poisonous chemicals on the caterpillars' food, so now hardiness had the advantage; the black types increased in numbers in each generation and in the course of seven or eight decades replaced the non-blacks and became the "normal" type. Experiments have shown that birds are effective

in eliminating moths that do not harmonize with their background, and that noxious chemicals in the food cause an increased death rate in non-black caterpillars. Furthermore, these experiments are beginning to give information on the actual selection—pressure that is operating—the quantitative advantage enjoyed by one type over the other. Similar experiments, on the appearance of DDT-resistant mosquitos, or on the acquired tolerance of bacteria to antibiotic drugs, are yielding important practical results. Biologists are now more and more turning to the detailed study of populations, either in nature or experimentally in special cages or enclosures.

On a more general level, increasing attention is being devoted to evolution as a phenomenon, to its course and its results. We are even beginning to be able to measure its speed: thus Simpson finds that the rate of evolutionary change is nearly three times as high in horses as in early ammonites.

Then there is evolutionary philosophy. It is becoming urgent to clarify certain evolutionary concepts. One of the basic facts of evolution as a process is the succession of types. A previously established group gives birth to a new type whose success, as shown by its rapid radiation into many sub-types, and often by the reduction of the parent type, demonstrates that it is superior or "higher" in its organization. We must attempt to give a scientific meaning to level of organization, to clarify what we mean by "higher" and "lower" types, and by biological "progress."

Darwin himself, in characteristic terms, rightly affirmed that natural selection inevitably caused the improvement of most organisms in relation to their conditions of life. We need to define biological improvement more closely, and to find out what type of improvement occurs in what conditions. Note Darwin's caveat: not all organisms are being "improved." Some types (and indeed many more than Darwin imagined) become stabilized and persist over long periods. This applies not only to "living fossils" like the Coelacanth fish *Latimeria* and reduced groups like the Reptilia, but also to highly successful terminal types, like higher spiders, modern birds, or ants, all of which have persisted for tens of millions of years with only minor change. Meanwhile, during the early stages of a group's adaptive radiation, numerous types appear which do not persist but become extinct, presumably because their organizational plan is less well integrated.

We need to discover what confers persistence and stability on a type, of whatever taxonomic rank. Is it genetic homostasis; is it efficiency of organizational pattern? Equally we want to discover what are the factors that restrict the progressive change of a group and set a limit to its further evolution, except by a rare break-through to a new and "higher" organizational level.

This links up with a rather radical change in approach.

Nineteenth century biologists were mainly interested in origins. Twentieth century biologists are becoming increasingly concerned with possibilities. The new idea of evolution that is emerging is of a dialectic process, tending to the realization of new possibilities, but constantly checked, in one trend after another, by limitations which it cannot transcend. Patterned colour-vision and temperature-regulation are examples of new possibilities realizable only at certain stages in evolutionary history. But there are limits to the acuity of vision and to the accuracy of homothermic regulation. The limits, of course, apply to biological evolution operated by natural selection. Thus the artificial (exosomatic) sense-organs manufactured by man (e.g. telescope, electron microscope) have enormously enlarged the scope of vision.

Some types, we are finding, possess potentialities which are normally unrealized, and are revealed only when new conditions are provided. In the laboratory, jackdaws are as good as human beings at non-verbal counting. Chimpanzees will create designs when given paper and paints, and will rival human performance when provided with rollerskates. Behaviour is becoming a focal point of evolutionary study. From one angle, it is being clarified by the application of information theory and the ideas of Cybernetics. From another, it is throwing light on the mind-body puzzle, by demonstrating the emergence, the diversification, and the steady intensification of awareness during evolution, and exploring the relation of different types of aware behaviour to the evolution of brain structure. The complexity of the behaviour of higher insects (e.g. of bees) suggests that their tiny brains operate in different ways from those of vertebrates: administration of drugs like lysergic acid are revealing wholly unexpected possibilities of behaviour and subjective experience in mammals: electrical stimulation is mapping the human cortex and showing us the material basis for memory.

Indeed, I would prophecy that the study of organisms as behaviour-systems is likely to be crucial for a better understanding of the problem of organization. Perhaps level of organization is best evaluated not merely by the number of differentiated functional and structural elements in a behaviour-system, but by the intensity of their interactions and the degree to which these interactions are integrated in a patterned whole. This, I think, is what is implied in Teilhard de Chardin's idea of p r o g r e s s i v e *enroulement* during evolution, which he develops in his remarkable book *Le Phenoméne Humain:* the quality and level of awareness is correlated with the degree of "tension" generated by the central interaction of "information" from different elements of the whole system, not merely with brain structure. However, much work will need to be done before such ideas on psycho-physical correlation become scientifically profitable.

Finally we come to the application of evolutionary ideas to man. Darwin, with typical modesty, concluded the *Origin* with the remark that with the acceptance of the idea of evolution, "light will be thrown on man and his history." At first attention was focussed on the animal ancestry of man, and much progress has been made in its elucidation. But to-day the generalization of the idea of evolution is illuminating the entire human problem.

To start with, we now realize that evolution operates in the whole of nature, and that it can best be defined as a one-way process of change in time which in its course increases diversification, creates novelty, and raises the upper level of organization. Thus, in a certain sense, all phenomenal reality is a single process of evolution.

But this general process is divisible into distinct sectors, separated by critical points, each with its own characteristic tempo and mechanism of operation, its own type of product. The three sectors we can now distinguish are the inorganic, the biological, and the human or psycho-social, the second arising out of the first, the third out of the second. To take only the two last-named, the main mechanism of biological evolution is natural selection, and its products are discrete organic species: while psycho-social or cultural evolution is based on the mechanism of the cumulative transmission of experience, and its results and its products are social groups not rigidly separated but capable of cultural interpenetration.

There have been many attempts to apply ideas derived directly from biological evolution to human affairs - notably to justify individualist laisse faire on the basis of the biological struggle for existence, or the principle of a master race from the succession of dominant types in palaeontology. But all such attempts are bound to be misleading since in man intra-specific competition is much less important than co-operative participation, especially when consciously embarked upon, and since succession in human history is of cultures, not of genetic (racial) types.

Sometimes, again, sociologists continue to think in evolutionary terms which have long been rejected by biologists, notably the assumption that evolution is always progressive, and is confined to a single line or trend. The Victorian idea of universal and inevitable progress, or Comte's procrustean framework of cultural stages, are examples.

Conversely, some historians and anthropologists who rightly reject such naive notions, throw the baby out with the bath-water and deny the possibility of genuine advance, either reverting to the idea of recurrent cycles, or emphasizing only the relativity of all cultural phenomena, such as social structure or morality.

To begin to comprehend cultural evolution, we must first of all make a thorough analysis of its underlying mechanisms, and

then survey it on the largest scale: it is useless to confine attention to civilizations, like Toynbee, or to primitive societies, like many anthropologists.

The first major difference between the biological and the psycho-social phase is that man, though a new dominant type, consists of only a single species. The incipient biological divergence which gave rise to the primary races of man was soon complemented by a process of convergence by migration and interbreeding. Of course marked cultural divergence has occurred, leading to the appearance of distinct cultures and types of society. But this trend too was succeeded by one of convergence: this process of cultural diffusion is always tending to spread more and more elements of culture over larger and larger areas. Though marked cultural differentiation remains within cultures, in respect of the basic mechanisms of communication and control there is a clear tendency towards global unification.

The second major difference is the immensely quicker rate of change seen in cultural evolution, and its tendency to show acceleration. This has now reached alarming proportions. It will be one of the tasks of the future to stabilize change at a manageable rate.

The third is that major advance is always dependent on new organizations of knowledge, either in the form of practical applications or of ideas and general approach.

Cultural, like biological evolution, proceeds by steps or stages. I will conclude with two relevant examples from the present. The fact of rapidly increasing population is obtruding itself forcibly on human attention; and it is becoming clear that this phase must tend towards stabilization if many difficulties and possible disasters are to be avoided. This will involve substituting the idea of human quality for mere quantitative increase.

The second is more radical. The process of evolution, as represented by man, is now, for the first time in its long history, becoming conscious of itself and of its nature. Man is the latest dominant type to be produced in evolution and the only one capable of further major advance. I would prophecy that one of the major scientific enterprises of the moderately near future will be a study of human possibilities and the evolutionary implications of attempts to realize them. If so, the idea of evolution, which became scientifically respectable a bare century ago, will find its most important application in the central problem of human destiny.

THE CAUSES OF EVOLUTION

Theodosius Dobzhansky

CHARLES DARWIN has demonstrated that man and other biological species now living have evolved from very different and simpler ancestors. The acceptance of this idea represents one of the turning points in the intellectual history of mankind. It is no underestimation of Darwin's greatness to say that his discovery was prepared by the work of his predecessors; it is even less a belittlement of his prestige to find that his theory of evolution has changed greatly during the century since it was proposed. Indeed, there has been an evolution of evolution, and Darwin's prototype resembles the modern theory about as much as Newton's resembles modern physics.

The geographic exploration of the world was making rapid strides during the eighteenth and the early nineteenth centuries. Many western nations were sending expedition after expedition to remote lands and seas. The purpose was to take possession of these lands, to discover new opportunities for commerce, and to confer the blessings of civilization on the natives, by forcing them to toil for their new masters. But these activities incidentally benefitted the science of biology. The personnel of some of the expeditions included a naturalist, whose duty it was to collect specimens of animals, plants, and other curiosities of the places visited. Charles Darwin served for several years as one of such expeditions of naturalists. The collections of natural history museums were rapidly becoming richer and richer; zoologists and botanists had to face the task of describing and classifying the tremendous variety of living things which inhabit our planet.

A method of classification of animals and plants was perfected by Linnaeus in 1758, exactly a century before Darwin and Wallace announced their theory of evolution. This method was to recognize the animal and plant species, and then to group them into genera, into orders, and orders into classes. It worked very well when applied to animals and plants of Sweden and of other countries of northwestern Europe with which Linnaeus was chiefly familiar. Sympatric species, i.e., species which inhabit the same territory, are usually discrete and unambiguously distinguishable entities. Linnaeus thought that this discreteness meant that every species represented a separate act of creation. If one adopts such a view,

there is no need then to ask why there is such an astonishingly great diversity of animals and plants in the woods, fields, and waters. Every species was made by God, and was placed where it belonged.

The situation has changed with the growth of the collections of animals and plants of different countries in various museums. When allopatric forms, inhabitants of different territories, are compared, the discreteness of species sometimes vanishes. A species may be represented by distinct races in neighboring territories, and races of remote territories may appear to be about as distinct as different sympatric species in the same territory. For example, many kinds of animals are represented by parallel but distinct forms in Europe and in North America. Are the wolves, foxes, bears, rabbits, squirrels, chipmunks, and elks of the Old and the New World races of the same species or are they different species? As their studies progressed, botanists and zoologists discovered more and more situations in which they were not certain where one species ended and the other began.

To be sure, such situations are a minority in the sense that the boundaries of most species are clear. For example, there are no living intermediates between the species of man, chimpanzee, gorilla, and orang. But the existence of even a minority of cases in which species cannot be unambiguously distinguished from races suggested that the species may not be the primordial units of life. Perhaps species might evolve from races by a gradual divergence and isolation? This idea was developed by Lamarck (1809) into a self-consistent theory of evolution. But Lamarck's contemporaries were not convinced that so radical a departure from the Linnaean view was necessary, and hoped that the concept of fixity of species might still be made to work.

The relentless accumulation of evidence for evolution compelled the acceptance of the new idea when this evidence was masterfully summed up by Darwin and Wallace in 1858 in their short essays, and especially by Darwin in 1859 in his classic work, *Origin of Species*. Darwin did not argue merely that species were products of evolution; he gave also a plausible account of what causes may have worked, and may still be working, to bring the evolution about. In other words, he not only examined the evidence for the occurrence of the process of evolution in the history of the earth, but also studied the mechanisms by which evolution takes place. He concluded that the main driving force of evolution is the adaptation of life to its environments, and that this adaptation occurs, chiefly if not exclusively, by means of natural selection of fitter variants in the process of what he called "the struggle for existence."

The description of the process of evolution as it actually occurred in the past, and the study of the mechanisms of evolution,

are certainly logically related problems, and yet an investigator may concentrate his attention on one or on the other problem. With Darwin's successors during the late nineteenth and the early twentieth centuries the first of these problems took precedence. It was necessary to prove beyond reasonable doubt that the living world as we see it is a product of the evolutionary process, and that the human species is kin to all life and a descendant of ancestors who were not men. This was the more necessary since the theory of evolution was, and to some extent still is, fiercely opposed, chiefly on non-biological grounds, by the adherents of the notion of fixity of created species. It seemed, accordingly, more important to ascertain that evolution did happen then to find out just what brought it about.

There is life almost everywhere on the surface of our planet - from alpine, arctic and antarctic snows, to tropical jungles and to the depths of the oceans; organisms vary in size from viruses visible only in electron microscopes to giant Sequoias. In the light of the theory of evolution, the study of this staggering but fascinating diversity made sense. Zoologists and botanists eagerly took up the task. The goal of their work was to unravel the phylogeny, the descent relationships of the organisms, and to trace how such different creatures evolved from common ancestors. Some of the attempts to do so were based on comparative studies of only the new living organisms, and some of the phylogenetic "trees" which zoologists and botanists constructed on this basis were not quite convincing. The advances of paleontology, of the study of fossil remains of the organisms of the past, improved the situation greatly. Acquaintance with the animals and plants which actually lived in the past provided the needed check and restraint on the freedom of speculation by the builders of phylogenetic "trees." The phylogenies became, at least in part, documented by the evidence derived from studies on fossils.

Beginning in the early years of the current century, a new trend in biology gradually gained ascendancy. The emphasis in biological research shifted from diversity of living things to their fundamental similarity, from morphology to physiology, from description to experiment. In the study of evolution this turned out to mean decreasing emphasis on construction of phylogenetic trees and a greater interest in mechanisms of evolution. That life has evolved became almost a commonplace; biologists now set out to discover what made it evolve. The causes of evolution are still operating today, and they may be studied in the field and in laboratories. We should be able to gain some understanding of the forces which have brought about the evolutionary transformations of the past, and which will bring about those of the future. An even more ambitious task now beacons to the biologists - man may learn to direct the evolution of living species, including that

of the human species. We need not content ourselves with the role of spectators and historians of evolution, we may aspire to be its guides and even masters.

In a sense, modern evolutionism has merely returned to Darwin, for the study of the causes of evolution was in the focus of Darwin's interest. However, biology has grown enormously since Darwin, and much of this growth has been in fields relevant to the study of the causes of evolution. A major break-through came in 1900 with the rediscovery of Mendel's laws and the subsequent growth of the science of genetics. A genetic theory of evolution was originated, largely independently, by Chetverikov (1926) in Russia, Fisher (1930) and Haldane (1932) in England, and Sewall Wright (1931) in America.

More recently there came another important development. What was originally a genetic theory of evolution was broadened to become a biological theory of evolution. Evidence from all biological sciences was synthesized and brought to bear on our understanding of how evolution takes place. The most important events in this synthesis were probably the publications of Mayr (1942) and Stebbins (1950) on evolutionary systematics, of Simpson (1944, 1953) and Rensch (1947, 1954) on paleontology and morphology, Schmalhausen (1949) on morphology and embryology, Darlington (1939) and White (1945) on cytology, and several others.

Mutation

All living beings grow and reproduce their like. They do so by converting the food which they find in their environment into likenesses of themselves and their ancestors. This process of self-reproduction, of like begetting like, is the essence of heredity. Heredity is evidently a conservative force, and as such is the antithesis of evolution. If the heredity were perfect, then the succeeding generations would always be precisely like the preceding ones. Evolution is a process which makes the descendants unlike their ancestors. Evolution is possible because the rigidity of heredity is sometimes and to some extent overcome by an opposing agency. This was perfectly clear to Darwin, but he did not know what this opposing agency was. It is mutation.

De Vries, the founder of the mutation theory, thought that a mutation brings into existence, in a single jump, a new species. In this he was certainly mistaken. Except for the origin of new species by doubling the chromosomal complements in interspecific hybrids (which is a rather special situation called allopolyploidy), the differences between species, and almost always also between races, are compounded of many mutational changes. What a mutation usually does is to change the structure of a single gene (gene mutation), or the arrangement of the genes in the chromosomes

(chromosomal mutation). Thus, a well-known mutation in Drosophila flies changes one of the genes which is necessary to produce the normal red eye color and makes the eye color white. Mutations in bacteria make them resistant or susceptible to antibiotics, able or unable to use certain substances as food, increase or decrease their virulence to their hosts, etc. White-eyed Drosophila can be crossed to the normal red-eyed one, and white and red individuals appear in certain proportions among the offspring. Surely they belong to the same species, just as blue-eyed and brown-eyed individuals in man do.

The mutation process supplies the raw materials of evolution; in fact, it is the only process known which does so. The mutants are the building blocks from which evolutionary changes may be constructed. A species can become heat- or cold-resistant, protectively or warningly colored, or able to subsist on a new source of food only if it is capable of producing mutants which, by themselves or in combination with other mutants, confer on their possessors the respective properties. The problem of mutation is obviously basic for an understanding of the process of evolution.

Mutations have been studied for more than half a century; much has been learned, and yet a geneticist is constrained to admit that his knowledge is decidedly inadequate. It is well-known that mutants are found considerably more frequently in the progeny of parents treated with X-rays and other high-energy radiations than without such treatments. This fact, first discovered by Muller in 1927 in Drosophila, has been so amply confirmed in most diverse organisms that there cannot be the slightest doubt that high-energy radiations are mutagenic also in man, although, of course, no experiments deliberately inducing mutations in man are possible. Auerback and others found that the so-called mustard gas and related chemical compounds are strongly mutagenic, and in recent years many new chemical mutagens have been discovered. Most of these physical and chemical agencies are non-specific in the sense that they do not induce a particular kind of mutation but simply increase the incidence of all sorts of mutants.

In recent years the highly intractable problem of specific mutagenesis, however, has shown signs of giving way. Avery, Hotchkiss, and others have prepared from some strains of bacteria responsible for pneumonia in man and other animals so-called "transforming principles," which, under certain conditions, induce quite definite mutational changes in other strains of such bacteria. What is more these transforming principles proved to belong chemically to the class of deoxyribose nucleic acids (abbreviated DNA), and DNA are known to be among the main constituents of the chromosomes, which, on other grounds, are considered to be the carriers of most, though not of all, genes. The possible future developments of this discovery may be very great,

if methods are invented to prepare and to deliver specific transforming principles to the genes of higher organisms, perhaps including man himself.

Yet, despite all the brilliant and important investigations mentioned above, we still do not know just what causes the so-called spontaneous mutation. For mutants occur also in the progenies of organisms not treated with X-rays, nor chemical mutagens, nor transforming principles. Such spontaneous mutants are on the whole rare, if one considers a given kind of change in a given gene. The known frequencies of spontaneous mutations per gene in Drosophila and in man cluster around the figure 10 , in other words, about one sex cell in 100,000 produced by a "normal" individual contains a mutation in a given gene. But one should keep in mind that the organism contains many genes; a sex cell of Drosophila is believed to have at least 10,000, and a human sex cell almost certainly has more. Moreover, the mutations which are utilized to derive the above frequency estimates are of necessity drastic changes, such as produce striking bodily malformations or diseases which kill the organism.

Mutations which produce slight alterations, for example such as make the organism grow a little larger or a little smaller, or make it develop a little darker or a little lighter color, may easily be overlooked. There is, however, some ground for the suspicion that small, perhaps barely detectable, mutational changes may actually be more frequent than the drastic ones. Taking all this into account, mutation is not a rare phenomenon. Some authorities estimate that perhaps as many as 10 per cent of human sex cells carry one or more newly arisen spontaneous mutants in each generation..

The Genetic Load

Here we must face an apparent paradox. Mutation is the only known process which supplies the raw materials from which evolutionary changes can be constructed. And yet, a great majority of mutations that are observed prove to be more or less injurious to their possessors. Many are lethal, i.e., they produce hereditary diseases which kill the organism before it is ready to reproduce. How can such degenerative changes result in organic evolution?

Let us analyze the problem a little more closely. In a growing culture of bacteria which are sensitive to the action of an antibiotic there arise from time to time mutants which are resistant to this antibiotic. These mutants arise regardless of whether the antibiotic is or is not present in the culture medium; to put it simply, the bacteria do not know whether they or their progeny will or will not encounter the antibiotic. Perhaps in an ideal world only useful mutants would arise, exactly when and where

needed. But our world is far from ideal; mutational changes in a gene are due essentially to errors in the process of gene reproduction. It is often said that mutation is a random process. This is misleading unless it is understood that the occurrence of a mutation is at random only with respect to the demands of the environment - a mutation may be neutral, harmful, lethal, or it may be useful. What mutational changes can or cannot arise in a given gene, however, is determined by the structure of that gene; the errors which may occur in the process of gene reproduction obviously depend upon what is being reproduced.

With a random process of this sort, it is actually to be expected that a great majority of mutants will be harmful. We may again use the relations between bacteria and antibiotics as a paradigm. In an environment free of antibiotics most, and perhaps all, mutants resistant to antibiotics are actually inferior in fitness to "normal" susceptible bacteria. But when a sufficient concentration of an antibiotic is added to the nutrient medium, all "normal" bacteria will be killed and only the mutants resistant to that particular antibiotic will survive. Hence, the mutation from susceptible to resistant is harmful in the absence but useful in the presence of the antibiotic; the reverse mutation, from resistant to susceptible, is harmful in the presence of the antibiotic but useful in its absence. Now suppose that a strain of bacteria is cultured for a long time on a medium of a given composition. The genes of this strain will then be those which are favorable for growth and reproduction on that particular medium. The mutations that will arise will almost always be harmful. The situation will be altered when and if the environment is changed - in a changed environment some mutants will prove useful.

Thus it comes about that the adaptedness of a living species to its present environment is to some extent in opposition to its capacity of becoming adapted to changed environments. Let us assume that the environment is absolutely constant in time. After the species has achieved its adaptation to that environment, all mutants will be harmful, and the suppression of the mutation process (if that could be accomplished) would raise the fitness of the species to the highest possible level. However, an unmutable species would be at a disadvantage if the environment started to change again, and would eventually die out because it could not bring itself into harmony with the new environments. The conflicting needs—for immediate adaptedness and for adaptive plasticity—can be reconciled only by a compromise; figuratively speaking, living species pay for their plasticity by the sacrifice of some individuals to disability and death from harmful mutations.

Just how great the genetic load is, in other words how many mutants are carried in natural populations and by how much the possible fitness is reduced thereby, we are only beginning to find

out. More or less precise data exist only for some species of Drosophila flies, and they disclose a situation which would have seemed amazing to the pioneers of genetics. Not only practically every "wild" fly, but in fact almost every chromosome in these flies, carries recessive genetic factors which, if they were carried in double dose (in homozygous condition) would incapacitate or even kill their carriers. The flies found in nature are "normal" and fit to survive only because these harmful genetic variants are carried usually only in single dose (in heterozygous condition). Reliable quantitative data for the human species are very scarce, but since a great deal of misery is caused by a variety of hereditary diseases, many of which are recessive, it is probable that the genetic loads in human populations are at least as heavy as they are in populations of Drosophila flies.

The problem of the genetic load has grown in interest and significance in recent years, especially in connection with the growing use and misuse of high-energy radiations, such as X-rays and atomic power. There is no doubt that these radiations are mutagenic (mutation-inducing), and hence the exposure of more and more people to such radiations will increase the genetic loads of human populations. Just how serious may be the consequences of this to the human species is not quite clear, and this matter cannot be discussed in detail in the present article.

Sex and Evolution

Whether a mutant is useful or harmful to its carriers is determined not only by the external environment but also by what other hereditary factors the organism has. As shown first by Mendel, the genetic equipment, the genotype, of an organism is a mosaic of more or less discrete corpuscles, called genes. If the parents differ in some genes, the progeny are hybrids, or heterozygotes, for these genes; when the hybrids form sex-cells, the latter may carry all possible combinations of the genes in which the parents differed. Thus, if the parents differ in n genes, 2^n kinds of sex-cells with different gene complements may be formed in the progeny. It is evident that the number of potentially possible genotypes rapidly increases as n becomes larger. With, say, 50 gene differences this number (2^{50}) is far greater than that of human beings who live or ever lived. This means only that every one of us has a genotype of his own, different from that of every other person (except that identical twins are usually alike in their genotypes). This is not so with organisms which can reproduce asexually. For example, a culture of bacteria descended by simple fission from a single individual may contain billions of cells, which except for the newly arisen mutants all have the same genes.

Sexual reproduction is, then, an enormously powerful mechanism for creation of ever new genetic equipments. To be sure, these new genotypes are merely different combinations of a relatively small number of genetic elements, genes. It should, however, be kept in mind that the development of an individual, from conception, to birth, to maturity, and to death, cannot adequately be described as a gradual accretion of effects of separate genes; all the genes act in concert, and what an individual is at any stage of his life is determined by interaction of the effects of different genes with each other and with the external environment. Sex is, therefore, the real fountainhead of biological individuality.

In organisms which reproduce sexually the process of gene recombination is even more important than that of mutation as a cause of the genetic diversity of individuals, and consequently as a source of the raw materials of evolution. Indeed, in lower organisms which reproduce asexually mutation is the only source of genetic novelty. On the other hand, populations of sexual organisms consist of individuals with different genes, and the recombination of these genes will go on generating new gene constellations even if no mutation will take place. To be sure, the variety of genes in sexual populations had arisen ultimately by mutation; however, these mutations may have taken place in remote ancestors of the now living individuals, and may have been perpetuated from generation to generation. Here, then, is another biological function of the genetic loads which, as we have seen above, populations of sexually reproducing organisms carry. Most of the mutant genes which are the components of the genetic loads may be harmful, but occasionally a constellation of genes may be formed which will be useful. Indeed, experiments in Drosophila populations have shown that the products of recombination of elements of two parental genotypes may be equal or superior or inferior in fitness to these genotypes themselves.

Many sexual species, including man, are outbred, since the individuals who mate are usually not close relatives. Most (though not all) cultures prohibit incest. However, some plant species, such as wheats or oats, are normally inbred; their seeds come mainly from self-pollination followed by fertilization of the ovule by the male element produced in the same flower. The normal fitness of an outbred species depends upon hybrid vigor or heterosis. This can be shown by experimental inbreeding of a normally outbred species, for example, by mating animals who are brothers and sisters for several generations. The inbred progeny usually shows progressive deterioration of vigor, and the loss of fitness may be so severe that the inbred line may die out. If, however, different inbred lines are intercrossed, their immediate progeny is restored at once to hybrid vigor. This is practiced on a very large scale in the hybrid corn industry; the corn seeds

which are sold for planting on farms are obtained by intercrossing four lines previously inbred by self-pollination. --Little or no heterosis results from intercrossing lines of normally self-pollinated species, e.g., of wheat.

The origin of hybrid vigor in evolution is still not well understood; this is one of the major evolutionary problems which has attracted much attention of investigators in recent years. It is connected with the problem of the genetic load in sexual populations discussed above. We have seen that most individuals of sexually reproducing species carry one or more potentially harmful recessive genes concealed in heterozygous condition. Individuals who are not closely related are likely to carry different harmful genes; the chance of the two parents who are not blood relatives carrying the same harmful gene is less than it is for relatives—brothers and sisters or even cousins; therefore, the chance of two similar harmful genes coming together and yielding an individual afflicted with a hereditary disease, malformation, or a weakness is smaller in an outbred than in an inbred progeny. Different inbred lines, however, are enfeebled in different ways - they carry different harmful genes; crossing them restores the normal heterozygous condition, and hence the normal hybrid vigor.

The above explanation of hybrid vigor is undoubtedly correct in part, but it does not tell the whole story. A mutant gene may be dominant, and its harmful effects may appear in heterozygous individuals, which carry one mutant and one normal (original or ancestral) gene. Or a gene may be recessive, and its effects may manifest themselves only in individuals carrying this gene in duplicate (homozygotes). Finally, a mutant gene may be harmful when in duplicate, but it may make the heterozygotes superior in fitness to the ancestral type. Thus, the Swedish geneticist Gustafsson obtained a mutation in barley which when present in duplicate kills its carrier by destroying the normal green pigment (chlorophyll); nevertheless, the plants (heterozygotes) which carry one mutant and one normal (non-mutant) gene are not only viable but, in fact under some conditions outyield the ancestral variety of barley. Allison and Ceppellini have reported data which suggest that certain genes in man which in homozygous condition are responsible for fatal hereditary diseases (sickle-cell anemia and Mediterranean anemia) may be useful in heterozygotes by making the latter resistant to certain forms of malaria fevers.

The crucial question is how frequent in human and other populations are genes which are useful (heterotic) when present in single dose (in heterozygotes). Bruce Wallace has recently described very important experiments which seem to show that in Drosophila flies a majority of mutations may be heterotic in heterozygotes, although they are more or less harmful when in double dose (in homozygotes). If this is confirmed, we shall have

to revise our ideas concerning the genetic loads which sexual populations carry. These loads may not be merely unavoidable evils. The adaptedness of a sexually reproducing species to its environments may actually rest on its representatives being heterozygous for many genes which could be harmful in homozygous individuals.

Natural Selection

A century ago Darwin wrote, ". . . if variations useful to any organic being ever do occur, assuredly individuals thus characterized will have the best chance of being preserved in the struggle for life; and from the strong principle of inheritance, these will tend to produce offspring similarly characterized. This principle of preservation, I have called, for the sake of brevity, Natural Selection." Darwin's statement remains valid today. We may only add that variations postulated by Darwin do occur; they are mutants and, in sexual organisms, gene patterns formed in the process of Mendelian recombination of genes.

Darwin argued that natural selection must take place; he claimed that the success of breeders in improving the qualities of domesticated animals and plants by means of artificial selection of desirable traits furnishes an experimental model of the action of selection in nature; he did not claim having observed changes produced by natural selection in non-domesticated forms. A modern biologist is in this respect in a somewhat better position. To be sure, he cannot reproduce in his laboratories the evolutionary process which has led to the transformation of our pre-human ancestors into the human species, or of the three-toed horse into a modern one, or vice versa. This is simply because such transformations entail long sequences of changes in many, perhaps in all, of the thousand of genes which the organism has. Since mutations in any one gene are rather rare events, it is infinitely unlikely that a human observer may see the many thousands of just the right consecutive changes occur before his eyes. Nevertheless, instances of selection acting on non-domesticated species have been observed.

Reference has already been made to the appearance of strains of bacteria resistant to the action of certain antibiotics. Beautiful examples of the emergence through natural selection of drug-resistant varieties are known also in relatively more complex organisms, namely insects. The depredations of insect pests have necessitated the invention of chemical substances, insecticides, which kill the offending insects. Some remarkable insecticides have been discovered which are poisonous to insects in concentrations so minute that they are not dangerous to man or to higher animals. The insects have not however surrendered without a struggle. House flies resistant to one of the most powerful

insecticides, DDT, have appeared in different parts of the world, and in many places have made this substance practically useless for the control of the fly. The body louse and a number of other insects have turned up similarly unwelcome surprises. It is not hard to see how insecticide-resistant varieties of insects may arise, and they have been obtained deliberately in experiments with Drosophila flies. Mutants resistant to DDT or to other drugs arise, presumably in many insect species, regardless of whether they are or are not exposed to the insecticides. These mutants are probably at a disadvantage compared to normal susceptible insects in the absence of the insecticides, but they are the ones which survive, and thus are favored by natural selection, when an insect population is repeatedly exposed to insecticides. As a matter of fact, Drosophila flies have apparently several genes capable of producing mutants resistant to DDT but otherwise different in behavior. What the function of these genes is in the normal insect is unknown.

Several species of moths, within the last century, have evolved darkly-colored (melanic) varieties in the industrial districts of England and of the European Continent. In some places the dark varieties have supplanted the original light populations almost completely. Ford, Kettlewell, and others have shown that the dark moths are inconspicuous on the background of the vegetation polluted by the grime and soot in the industrial districts, and highly conspicuous, and therefore exposed to the attacks of insectivorous birds, in districts not so polluted. The ancestral light moths are, on the contrary, more conspicous on the polluted than on the clean vegetation. Natural selection, accordingly, has favored the replacement of the original light by the dark moths in industrial regions.

The objection can be made that in the above (and in other similar) cases the changes have been observed in organisms which live in environments interfered with by man. This does not, however, make the selection responsible for the changes any less "natural." Man has modified many environments both radically and rapidly; some animal and plant species were unable to become adapted to man-modified environments and died out; other species responded by selection of genetic endowments which made them adapted to coexist with man. Furthermore, the action of natural selection on organisms not interfered with by man has likewise been observed. The succession of seasons, summers and winters in temperate and cold climates, wet and dry seasons in the tropics, causes drastic changes in the environments of many organisms. The genetic endowments which are most favorable at one season are not necessarily the best at the following season.

Some creatures, particularly those which produce several generations per year, respond to seasonal changes in their

surroundings by genetic reconstructions. Especially clear cases of this sort have been observed in a very recondite trait of a species of Drosophila flies in western United States. The populations of this species are mixtures of individuals with different structures of their chromosomes. Certain chromosome structures are particularly favorable to the flies during the spring months, and other structures during the summer. The generations of the fly which live in spring are thus exposed to natural selection which favors different chromosome structures than those favored by selection in the summer generations of the same fly. Some chromosomes are, therefore, more frequent in spring than in summer, while for other chromosomes the reverse is true. Of course, since more or less the same seasonal environments recur every year, the changes induced by natural selection in the fly are also cyclic. And yet, changes lasting for several years have also been observed in the same species of Drosophila. Some of them are apparently due to climatic variations, others are perhaps of a more permanent character.

Competition and Cooperation

The century which has elapsed since Darwin and Wallace first formulated their theory of natural selection has not only strengthened the factual basis of the theory but also changed the emphasis in studies on the action of selective processes. Darwin acknowledged that the idea of natural selection was suggested to him by the writings of Malthus, who argued that the growth of human populations tends to outrun their food supply. The numbers of men, and by extension, also of animals and of plants, are limited by the "Malthusian checks"—hunger, war, and disease. The "struggle for existence," used by Darwin in a metaphorical sense to state the necessity of the organism being in harmony with the conditions of its existence, was understood by some of his followers as referring to active competition and combat between individuals of the same and of different species for limited food and space resources. This fitted remarkably well with the predilections of some nineteenth century writers, who liked Tennyson's description of nature as "red in tooth and claw," and such slogans as "eat or be eaten."

The inevitable reaction took the form of accusations of Darwin for allegedly having invented a justification of cruelty and inhumanity - things remote from Darwin's mind. Kropotkin and others attempted to argue that "the animal species, in which individual struggle has been reduced to its narrowest limits, and in which the practice of mutual aid has attained the greatest development, are invariably the most numerous, the most prosperous, and the most open to further progress." In other words,

natural selection is promoted not by competition but by cooperation. The modern versions of the theory of natural selection make the competition-cooperation alternative unnecessary. We can here attempt only to indicate the broad lines of this theory.

Suppose that a population of house flies is exposed, generation after generation, to an insecticide containing DDT. Some individuals in this population carry genes which make them relatively resistant to DDT, while others are killed more easily. Since the resistant individuals, on the average, leave more surviving progeny than do the non-resistant ones, the proportion of resistant flies in the population will gradually increase. Eventually the non-resistant form may disappear entirely, and the population will consist of carriers of the genes for resistance. The carriers of these genes possess, in an environment containing DDT, an adaptive value, or fitness, greater than that of the carriers of the genes for non-resistance. The fitness of a genotype is measured in terms of its contribution, in a given environment and in relation to the contributions of other genotypes, to the genetic endowment of the succeeding generation. Knowing the fitness in a given environment of the genotypes of which a population is composed, one can predict the composition of this population in the future generations.

Herbert Spencer spoke of natural selection leading to "the survival of the fittest." All too often this phrase seemed to suggest, especially in application to man, a conqueror who has destroyed his competitors in a mortal combat. But the fittest may as well be a much less romantic figure - a parent of the largest surviving progeny, who has avoided all combat by well-timed submission. Biological fitness is promoted sometimes by competition and combat and at other times by cooperation and submission. Natural selection is from first to last opportunistic; it furthers the genetic equipments which favor reproductive success, no matter how achieved. And it has the advantages as well as the weaknesses of all opportunisms - it maximizes the chance of immediate success, but it often does so at the cost of trouble in the long run. For the reproductive success is not a wholly adequate measure of excellency of a biological organization. It does not necessarily promote the ability to become adapted to future changes of the environment.

Thus it comes about that, as the study of fossil animals and plants abundantly demonstrates, the creatures now living are the descendants of only a fraction of the species which inhabited the ancient seas and lands. Most of the animals and plant species of the past epochs died out without issue. They died out because they were adapted to live in the environments which ceased to exist, and they were unable to change in accordance with the demands of newer environments. Strange though this may seem, the most

probable end of most evolutionary lineages is extinction, and this despite the fact that the evolutionary transformations in these lineages are under the control of natural selection. Natural selection acts in terms of the fitness of a genetic equipment in the environments which exist here and now; it has no prescience of the future.

The lack of plan or foresight in natural selection has been a stumbling block which prevented the acceptance of the modern biological theory of evolution by many thinkers in and out of biology. Indeed, is it conceivable that the interaction of such "blind" and "mechanical" processes as mutation, sexual reproduction, and natural selection could bring about the emergence of such complex and beautifully contrived organisms as higher animals or man? If one tried to imagine that the body of a living being arose out of non-living substances at once in the nearly perfect functional condition in which we find it in the present, its origin "by chance" would be infinitely improbable. But this is not the way the living bodies have developed. The body of man, or of any other organism, is a product of a historical process extending back for perhaps two billion years, to the dawn of life. It did not arise by a lucky throw of the genetic dice - it developed and became perfected, slowly and laboriously, by trial and error of countless changes which have arisen on the way, the tremendous majority of which were rejected as unsuitable.

Fisher correctly said that natural selection is a means whereby things in the highest degree improbable may be realized. We may add that the emergence of a living body in evolution should not be compared with building a machine in a modern factory. A machine cannot function until the last part of the mechanism has been put in the proper place by human hands or by another machine contrived by an engineer. Biological evolution is rather more like the development of a complex modern machine from simpler and less efficient models, and of the latter from the simple sticks which our subhuman or even prehuman ancestors first used to supplement the action of their muscles and their limbs.

Natural Selection and Human Evolution

The above considerations have a bearing on perhaps the most fateful problem which biology has to face. This is the problem of the evolutionary future of mankind. The human species, like all other species, is a product of biological evolution. But in man the biological evolution has transcended itself; it has led to the emergence of a novel and immensely powerful mechanism of adaptation to the environment. This mechanism is the human culture. All biological species become adapted by changing their genes in accord with the demands of their environments. Natural selection

is the process which brings these changes about. The human species is able, in addition, to become adapted by changing its environments in accord with the demands of its genes. Understanding and invention are the means which make this possible.

Does this mean, however, that the evolution of culture has brought the biological evolution of our species to a halt? Or is it possible that our biological evolution continues, but that the environments created by human culture may misdirect this biological evolution, perhaps leading to the eventual extinction of the humankind? There exist proponents of the first as well as of the second possibility. We do not know as yet enough to return an unambiguous answer to this momentous question.

Research in this field is urgently needed. There is, however, one widespread misunderstanding which may be cleared up now. This is the belief that all was well with human evolution so long as our species was under a watchfull control of natural selection, and things are going badly now because under conditions of civilized living natural selection no longer operates. This belief is based on two fallacies. The first of them is that, as already explained above, the action of natural selection can by no means guarantee the welfare of a species, and even cannot always secure it from extinction. The second is a subtler one, and is concerned with a misemployment of the word "natural" to mean the kind of selection to which mankind was exposed in its rude pre-civilized state.

It is true that modern medicine saves the lives of many persons who would be eliminated under the conditions of life prevailing during the Stone Age. But it means only that the adaptive value of a genetic equipment is a function of the environment. Weak eyesight might have been a fatal drawback in a paleolithic hunter, but it can often be corrected by glasses; bad teeth could be deadly in a primitive man, but now the defect may be mitigated by artificial teeth; and difficulties of childbirth have lost some of their horrors because of the progress of surgery. Consider, however, the other side of the ledger. It is not at all improbable that greater nervous and mental resilience are necessary to withstand the pace of living in modern cities than was needed in nonliterate societies. Natural selection in our ancestors promoted the capacity to extract maximum energy value out of their food which was often in short supply; a part of modern mankind, however, is exposed to superabundance of food, which threatens obesity and cardio-vascular disorders in the carriers of some genes.

Natural selection is obviously acting in all human societies, but it is acting in different ways. There is as little reason to expect that it always will keep up the human adaptedness to the conditions of the Stone Age as to hope that it has prepared us to cope with the environments of the Atomic Age. Selection is acting only

as the conditions of the present make it act. This does not mean, however, that all is necessarily well with the biological underpinnings of human nature. Man cannot rely exclusively on natural selection any longer. The time is approaching when man will have to take the management of his evolution in his own hands. To carry this appalling responsibility, he will have to summon all his knowledge and his wisdom. For the time being he has no surplus of either.

CHRISTIANITY AND DARWIN'S REVOLUTION

Reinhold Niebuhr

HISTORICALLY, the discovery by Charles Darwin that biological species were subject to mutation was the capstone of a long erosion of Aristotelian science, which assumed the immutability of the forms and structures of both nature and history and which regarded the temporal flux as merely the cycle of "coming to be and passing away" of the individual representatives of the species, the essence or the structure of existence, which their life explicated. The challenge to this Aristotelianism began in the Renaissance and was initially limited to a consideration of the more obvious development of historical structures. The achievement of Darwin was to prove that natural as well as historical structures were subject to temporal development. The concept of "natural selection," while partially validated, probably obscured the mystery of the emergence of novelty in time. Certainly no natural or scientific cause could be given for the radical uniqueness of Homo Sapiens, with his endowments of reason and spirit, which enabled him to transcend the temporal flux in which he was undoubtedly involved. The long controversy about the "missing link" is indicative of the surmise of many scientists that, while Darwin's *Origin of Species* had undoubtedly proved that man was chronologically related to the brutes, even as any analysis of his physical structure had long since proved that he was structurally related, nothing in the evolutionary story could give an adequate account of the radical character of the emergence of the novelty of man.

Incidentally, while it is obvious that man's unique capacities are subject to development both individually and collectively, it is significant that all accounts of this development which seek to ascribe the uniqueness to this development are forced to assume in their argument the distinctively human capacities which they try to explain in evolutionary terms (as, for instance, in George Meade's *Mind and Society).* The rational capacities of man are obviously subject to development, for both children and primitives lack the capacity for conceptual knowledge. There is, nevertheless, no record of an animal herd gradually evolving into a human

society, though it is also significant that primitive societies have some similarities with animal herds.

The resistance of the religious community, or more precisely all religious communities, to the Darwinian discoveries in science was so stubborn and so pathetic that it was almost universally regarded as the final rear-guard action of a dying religious faith embattled with an advancing science. The religious attitude was so stubborn because Christianity had for years compounded Aristotelianism with the Biblical doctrine of creation. Of the two it was the Aristotelian science of fixed forms and species which seemed to be the most formidable opponent, particularly since many scientists challenged Darwinism for Aristotelian reasons. But in the minds of the pious the chief reason for challenging Darwin's conclusions were that they compromised both the majesty of the Creator and the dignity of the creature who had been said to have been made "In His Image:" that is the dignity of man.

One reason why the gradual acceptance of the Darwinian thesis proved not to be lethal to religious faith was that the Biblical doctrine of creation was not as dependent upon Aristotelian ontology as Christians had traditionally assumed. The two were, in fact, in contradiction to each other; but that was not discovered until Darwin's triumph shattered the relation and also prevented Christian obscurantists from using the doctrine of creation to obviate the necessity or possibility of inquiring into the sequence of causes. For actually it is in precisely the analysis of these sequences that two facts become apparent. One is that every event has a previous cause, as stated in the Latin maxim *ex nihilo nihil sit.* The other is that no previous cause is a sufficient explanation of a previous event. This becomes particularly apparent in the emergences of striking novelties in the evolutionary chain, of which the most notable are the emergence of organic life and the emergence of man. Here we have the most obvious glimpse into the mystery of creation and may be prompted to realize that Aristotelianism and Biblical doctrines are not natural allies but contradictory conceptions. The compounding of these contradictory conceptions was one of the consequences of the confluence of Hebraic and Hellenic culture, which reached its height in the noonday of the medieval period of Western culture.

The Hellenic component of our culture sharpened the rational instruments for the advances of all our sciences by its assumption that there were rational elements in nature which the reason of the mind could explore. Mind and nature had affinities insofar as the penetration of the one could explore the consistencies of the other. Nature is rational in terms of its consistent coherences, which is why mathematics and physics are so closely related. The inner consistencies of mind are related to these natural consistencies, which is why logic and mathematics are so closely related.

Nature is nevertheless not completely rational. That is why science must move by induction rather than deduction and wait upon the fact, which can not be deduced from the coherence and consistency of known facts. The first science in which Aristotelian deduction was successfully challenged was astronomy. Ideally, the triumph of Copernicanism should have shattered the partnership of Aristotelianism and Christian piety and made room for the recognition of the "irrationality of the givenness of things" and for the necessity of inductive as well as of deductive procedures in science. Ideally, the Biblical doctrine of creation, or the recognition that there is a mystery of creation above and beyond all of Aristotle's four causes, should have made room for genuinely empirical science. Actually the partnership, though challenged, lasted from Copernicus to Darwin. The greatest philosopher of the last generation, Alfred Whitehead, finally clarified the relation between causes and creation in his monumental work, *Process and Reality* in which he proved that even the most rational account of the temporal processes could not give a picture of a self-explanatory process, but is forced to posit a "primordial God" as the "principle of concretion." For there is no rational explanation of why just this potentiality of all possible potentialities should be realized in concreteness.

All this was unknown in the age of Darwin, and the hosts of piety were embattled against the impiety of the dread Darwinian conception. It is a well-known drama now with Bishop Wilberforce, otherwise irreverently known as "Soapy Sam," and the redoubtable Thomas Huxley, carrying on the debate in the main theatre which was reenacted in almost every village and hamlet. Religious people ought to remember with some embarrassment that the religious arguments were not always honest or logical and that it was Thomas Huxley who insisted on scrupulous honesty, being in perfect conformity to the great virtue of the scientific enterprise, which was and is to "follow the evidence." Huxley was honest enough to challenge the conclusions of those who drew wrong moral and sociological conclusions from biological facts in his *Romanes Lecture.*

The world of science with its scrupulous honesty in weighing evidence would regard religious piety from that day to this a breeder of dishonesty, zealously "telling a lot of little lies in the interest of a great truth," (Clutton Brock) perhaps of two great truths: the mystery of creation and the unique dignity of man. Science was meanwhile "telling a lot of little truths" about causes, which could be fashioned into a "big lie." That falsehood was that historical processes and natural processes were sufficiently identical to make the same scientific method applicable to both fields. Before we discuss the consequences of this illusion we must delay for a moment to record that pious statesman of the

type of William Gladstone, and more belatedly our own William Jennings Bryan, who futilely lent their rhetorical skills for the purpose of arresting the march of the Darwinian "heresy." The Scopes trial, in an obscure Tennessee village, was the last act in the drama of ignorant piety challenging the march of science, which was, among other achievements, to destroy the partnership between piety and obscurantism, and between religious faith and Aristotelian ontology. It must be confessed that the obscurantist temptation to piety is never overcome; because the religious symbols of ultimate meaning are poetic rather than exact and scientific, and the fearfully pious are always tempted to buttress their validity by a frantic adhesion to some outmoded science, against the challenge of a marching science, which always has immediate truth on its side but which always threatens to construct a scientific world picture in which no meaning can be found for man in his grandeur and his misery.

Subsequent developments, after the triumph of Darwin, proved that the religious impulse to defend the unique dignity of man were not as foolish as they seemed, though the methods of defense were both foolish and futile. For the triumph of Darwinism in biology led to false conclusions in the field of morals in particular and to false interpretations of human history in general.

Perhaps the most glaring example of a triumph of truth in the field of the natural sciences leading to error in the field of the social sciences was the emergence of "Social Darwinism." This creed, which tried to transfer the principle of "the survival of the fittest" to historical and moral issues, gave support to the remnants of the laissez faire principles of classical economics, derived from physiocratic illusions of the Enlightenment in France. The illusion was that history was governed by "laws of nature," with which one must not interfere. Social Darwinism served to dull the conscience of the Western world to the injustices of its rising industrialism. It prevented the adoption of the ameliorations of economic inequality, the creation of adequate equilibria of power by which the West was ultimately saved from communism; but the illusions were potent enough to delay action so that the Marxist rebellion could be initiated among the desperate industrial classes of the Continent. Thus a "class struggle" was prompted which brought Western civilization to the very edge of disaster.

Herbert Spencer was not a social Darwinist, but he also regarded the Darwinian triumph as validating his historical fatalism and optimism. He agreed with the social Darwinists at least on the point of obscuring the fact that man has an ambiguous place in the historical process; for he is both creature and creator in the process, and he dare not abdicate his responsibilities as creator or forget his importance as creature.

The post-Darwinian era elaborated a confusion of voluntaristic and deterministic ideologies; but even the voluntaristic ideologies, such as that of August Comte, which disputed the determinism of Spencer, also drew inspiration from the basic error introduced by Darwinian biology into historical studies. For Comte based his historical optimism on the hope of an increasing scientific control of historical forces by an elite of scientific creators, who could only manage historical processes as if the human material were as maleable as the forces of nature. The Comtean type of voluntarism was mistaken for the simple reason that no elite of historical managers was godlike and no "stuff" of history to be managed was as "natural" as the theory assumed. The theory, despite its voluntaristic character, was thus derived as clearly from the error of equating history with nature as the Spencerian theory. No one can hold Darwin responsible for these errors. They are worth recording only to illustrate how human history is a curious drama in which truth sometimes is rescued from error and more frequently error is distilled from the truth. The illusions of Comtean voluntarism did not generate immediate perils for civilization because the elite who were to manage history were not sharply defined and there was no political program for endowing them with the omnipotence, which their destiny required. It remained for the apocalyptic creed of communism to designate such an elite, the "proletariate," with precision, and to elaborate a political program which would make their pretensions dangerous by arming them with power to manage the historical forces toward the dreamed of apocalyptic end.

These various forms of deterministic and voluntaristic optimism which the discoveries of Darwin in biology prompted were confined on the whole to secular thought. But it must be recorded that the general historical optimism, whether deterministic or voluntaristic, invaded the religious communities. It is perhaps one of the greatest ironics of history that one part of the Christian church, that part namely which was not in creative relation to modern culture, opposed Darwinism in the field where it was undoubtedly true. But the other part of the Christian community which was in creative contact with the culture, accepted the erroneous conclusions, which seemed inevitably to flow from the discovery of Darwin, and added religious emotion to interpretations of history which were obviously false.

This was particularly true in America, where the indeterminate possibilities of a great nation, expanding on a virgin continent, accentuated the mood of historical optimism, which was initiated in the Renaissance and developed through the centuries until the evolutionary theory of Darwin seemed to be the final validation of the mood. The most outspoken and vapid Christian exponent of this optimism was John Fiske, who was equally assiduous in

refuting the errors of the religious opponents of Darwin and in propogating the errors of the secular proponents of "Darwinism." Fiske's *Cosmic Evolution* was a perfect expression of the historical optimism which characterized Western culture at the end of the nineteenth and the beginning of the twentieth centuries. The optimism was so pervasive because both the voluntaristic versions and the deterministic accounts of historical development contributed to it. Progress was assured in the one case by natural forces, history being regarded as merely an extension of nature. Darwin's discoveries did not create this optimistic determinism, but they seemed to support it. In the other case it was "science" and the "scientific method" which were relied upon to put man in gradual control of historical as well as natural forces, thus guaranteeing the progressive elimination of all manner of evil. The purely deterministic theories failed to measure human freedom, which distinguished man from the brutes and history from nature. The voluntaristic theories, whether Comtean and liberal or Marxist and communist, looked forward to a change in the human situation, either by revolution or evolution, which would alter the ambiguity of man's relation to the historical process in which he was both creator and creature; and make him unambiguously the creator of historical destiny. These theories were primarily secular, but they were so dominant in the culture and expressed the mood of the age so accurately that the portion of the Protestant church which was in more organic contact with modern cultural movements completely capitulated to the optimism.

Some violence had to be done to the traditional tenets of the Christian faith to approach conformity between it and the ideas of progress. The idea of Divine providence was rather easily translated to that progress and would seem to be a more accurate description of what the idea of providence intended. The religious vision of the "Kingdom of God," which had always given the modern mind some difficulty, was interpreted to mean the goal and fulfillment of all historical striving. The Biblical recognition of the importance of man could not be easily transmitted or transcribed to fit into the optimistic scheme, but they could be subordinated to the idea that God had called man to be "co-worker" with him. The secular world generally considers the rearguard action of Christian orthodoxy, in vainly trying to refute the undoubted scientific achievements of Darwin, as an undignified and pathetic spectacle. But modern culture is not generally aware that the uncritical appropriation by Christian liberalism of the illusions, propogated by those who drew false conclusions in the realm of history from truths, which were valid in the realm of nature, was just as futile and pathetic. These errors were not, however, as noticeable because they were committed, not in the teeth of opposition to the main currents of modern culture, but in consonance with its mood.

By a curious irony of history the optimism which was so confidently proclaimed at the end of the past century and the beginning of the current century, was cruelly refuted by the weight of historical facts, beginning with the World War of 1914. The dreams of a "parliament of mankind and federation of the world" thus turned into the reality of a conflict on a world scale. The hope that "methods of persuasion" would gradually overcome "methods of force" was disappointed by the realities of more and more total war because modern technical civilization and democratic government were more capable of harnessing the total resources of the community for any end the community intended to achieve, of danger it intended to counter.

The Second World War followed quickly and presented Western civilization with the agonizing choice of allying itself with one despotism in order to overcome what seemed to be a worse one. But the allied despotism of communism proved in the end to be more an enduring threat to the peace of the world. Its apocalyptic vision of a perfect brotherhood of nations and a classless society, once a revolution had eliminated the institution of property, captivated and still captivates the nascent nations of the Colored Continents, while meanwhile the prophets of this new political religion became the priest-kings of despotic utopian states. None of these terrible emergences and emergencies had been anticipated in the "century of hope." Nor was it anticipated that the continued advancement of the natural sciences would gradually result in the discoveries of nuclear physics and that these achievements would be quickly pounced upon by fearful governments so that the scientists became the armorers of the nations in a "nuclear age" in which the world has the possibility of completely destroying civilization by the lethal and destructive efficacy of its nuclear weapons.

Thus history proves in contemporary experience that man's freedom over nature has both destructive and creative possibilities and that these possibilities grow together with the freedom. Our experience also proves that the triumphs of the natural sciences which have created nuclear energy and nuclear weapons cannot be matched by equal triumphs of the "social sciences" or any other wisdom which might bring this awful energy under social control. This would seem to suggest that man is destructive as well as creative in his unique freedom precisely because the freedom to transcend natural finitude is not as absolute as the previous century supposed; and that there is no possibility of making it more absolute.

It would be foolish to hold Darwin responsible for all the foolish illusions which were generated in his name. It would also be idle to celebrate the triumph of science over religious obscurantism without noting the triumph of enlightened religion and the consequent triumph of illusion.

Thus, the imposing achievements of a great scientist in the past century entered into the complex pattern of man's cultural history and prompted both enlightenment and illusion about the human situation.

THE CONCEPT OF EVOLUTION IN PHILOSOPHY

Oliver L. Reiser

NO DOUBT it is mere coincidence that the year which saw the publication of Darwin's *Origin of Species* was also the year in which John Dewey was born. But it is no accident that the long-range consequence of both events was to change the character of philosophy by giving the death-blow to the "spectator theory of knowledge" which had been so much a part of philosophy since the time of Plato. Considered in the light of this development, Dewey is certainly correct in his analysis, in his early essay (1910) on "The Influence of Darwin on Philosophy," where he announces that the greatest dissolvent in contemporary thought of old questions and the greatest precipitant of new methods and problems is the scientific revolution that found its climax in Darwin's book, the *Origin of Species*.

All students of contemporary society know that Dewey himself contributed much to carrying forward the "scientific revolution" by extending its influence into social science, ethical theory, and education. In Dewey's own words: "In laying hands upon the sacred arc of absolute permanency, in treating the forms that have been regarded as types of fixity and perfection as originating and passing away, the *Origin of Species* introduced a mode of thinking that in the end was bound to transform the logic of knowledge, and hence the treatment of morals, politics, and religion." As a forceful advocate of the evolutionary approach to human nature and social institutions—the content of what is now tormed the "behavioral sciences"—Dewey doubtless accomplished more than any other philosopher of our century in making the biological conception of human intelligence—the theory that *thinking is problem-solving activity*—an integral part of our methodologies. The effects of this change in viewpoint are simply enormous—at least so the Instrumentalists inform us.

On the other hand, there are those who will contest the soundness of the Instrumentalists' interpretation of the course of events. They will dispute the foregoing appraisal of the influence of Darwin's work and will affirm vigorously that the effects of evolutionary thinking did not constitute the tremendous impact alleged

above. The advocates of this more moderate assay of Darwin's influence—that is, the "downgraders" of the potency of evolutionary ways of thinking—will rest their case on the historically correct observation that the idea of evolution, i.e., the doctrine of the gradual change from earlier and simpler forms to later and more complex forms of living things, is not a new idea; therefore its reaffirmation at the time of Charles Darwin was no new challenge or "revolution" in thinking. They may even go so far as to argue, as does G. T. W. Patrick in his Introduction to Philosophy, that "the history of the doctrine of organic evolution goes back to the ancient Greeks. Aristotle not only taught the doctrine of evolution, but he had, what Darwin lacked, a theory of its *causes*." In support of this contention, those who adopt this point of view will point to the circumstance that many pre-Darwinian evolutionists—not only Buffon, Lamarck, Erasmus, Darwin, Goethe, and others among moderns, but as far back as the pre-Socratic nature philosophers among the ancient Greeks—had well-conceived theories of the processes of evolution and their natural causes.

Thus in short order—indeed quite abruptly—we are catapulted into the middle of a lively controversy. The untangling of the issues which underlie this dispute will throw light on the motivations at work in philosophy which, even now, have their contemporary reverberations.

As a point of departure for my own interpretation of events, I return to the viewpoint illustrated by the quotation from Patrick. If those who deny that Darwin's work had the impact which Dewey alleges rest their case on the fact that twenty-five centuries ago the early Greek philosophers, men like Thales, Democritus, Anaximander, and others, were evolutionists, they may be overlooking a very obvious point, namely, that between the early Greeks and modern times an event of unique importance had already taken place and this made all the difference in the world with respect to intellectual outlook. This event, of course, was the influx of the Judaeo-Christian world-view into the main stream of Western thought. For better or for worse, the Hebrew-Christian tradition was soon committed to an anti-evolutionary view. This is obviously a case of historical determinism: having embraced the "special creation" theory of *Genesis*, and recognizing the *Old Testament* as the spiritual precursor of the Christian ideology with its inherent notions of "original sin," the Messianic role of the *Savior*, and the like, the early Christian Fathers had no escape from the theory that the human family began with our first parents, Adam and Eve, in the Garden of Eden. The effect of this was certainly to forestall the application of evolutionary ideas to the problem of the "descent of man."

The second coercive influence in committing the early

Christian Church to a non-evolutionary viewpoint was the historical circumstance that some influential converts to Christianity, especially St. Augustine, had previously espoused Plato's theory of ideal forms, and this neo-Platonic metaphysics confirmed the Patrologists in their acceptance of the doctrine of fixed or changeless types in the hierarchy of species. When this neo-Platonic formulation was amended to conform to the Aristotelian modifications of Platonism which Thomas Aquinas steamed and pressed into the mold of Scholastic theology, the non-evolutionary viewpoint was solidified—even beyond what St. Thomas had desired. Thus in Thomism we have the apotheosis of Aristotelianism as logic, as metaphysics, as natural science, and as ethics.

This brings us to a crucial issue in philosophy, whether it be ancient, medieval, or modern. Did Aristotle in fact have a theory of evolution, as some scholars allege? Or, as I believe is really the case, is it a fact that Aristotelianism did not have a theory of evolution, and indeed by its very nature cannot develop a theory of evolution? In that event, Aristotelianism is inherently opposed to the evolutionary way of thinking, and Dewey is quite correct when he avers that Darwin's book was inescapably destined to work a revolution in Western thought,—a revolution made all the more inevitable by the Christian Aristotelianism which stifled the emerging philosophy of evolution of the pre-Aristotelian Greek nature philosophers.

It is true that some contemporary Thomists, both inside and outside the Roman Catholic Church, have approved an evolutionary biology. The prototype for this sympathetic attitude toward evolutionism—freed, however, from Darwin's theory of natural selection—was provided by St. George Mivart. Such compromises are now quite common, both in the Roman Catholic and Protestant branches of the Christian Church. But such compromises, insofar as they still retain vestiges of Aristotelianism, are products of discordant synthesis. Certainly this is so if our thesis is correct that Aristotelianism is in principle a non-evolutionary viewpoint. Aristotle's philosophy is an "essentialist" doctrine in the sense that, as the Existentialists would say, "essences precede existence." To see why the Platonic-Aristotelian metaphysics *must* lead to a non-evolutionary type of explanation let us retrace the main outlines of the Aristotelian form of essentialist philosophy.

According to the metaphysics (or "first philosophy") of Aristotle, the individual is the union of *form* and *matter*. In the development of any organism as a member of a class (type), the inner agent of development (or *entelechy)* brings about a process that culminates in the realization of a completed end—a *telos*. This formal principle was given the name *eidos*, a term which the Scholastics translated as *species*. The Aristotelian schematism of forms in nature thus was embodied in a hierarchy of types

or species arranged according to the essential characteristics *(essences)* which defined the classes. "Induction" thereby becomes a kind of intuitive identification of individuals within their proper classes. Thus through the prevailing influence of Aristotelianism, the idea of the "fixity" of species was embedded in the formal structure of Western thought. The Aristotelian method of definition according to genus, species, and differentia, was grafted into the "tree of Porphyry" as the logical machinery whereby individuals (and the classes in which they are contained) are in turn subsumed under the proper genera within the "hierarchy of essences"—to use a term which contemporary Thomists like Dr. Mortimer Adler still find congenial. This Aristotelian mode of thinking was stabilized in biological science through the work of the Swedish botanist, Linnaeus. The Linnaean classification produced the modern system of taxonomy which combines a generic name with a specific name in accordance with the Aristotelian form of definition *per genus et differentia,* which of course presupposes the Aristotelian *law of excluded middle.* The inherent limitations of this type of explanation have been exposed by Kurt Lewin in his comparison of the Aristotelian versus the Galileian modes of thinking.

Once modern science and philosophy achieved their emancipation from bondage to the Aristotelian tradition, the changes came thick and fast. More than any other single concept invented by the mind of man, the idea of evolution has been a seminal one. It has been "used" in many fields for a wide range of interpretations (and misinterpretations). Even the notions of "relativity" and "psychoanalysis" have fallen short of the potentialities of "evolution" in their procreative powers.

The facts and theories of evolutionary thinking have constituted the woof and warp on the loom of speculation on which imaginative patterns of varying design have been woven. Consider this chapter in the mental-social recapitulation of Western thought: Herbert Spencer and John Fiske interpreted evolution as a law of cosmic progress; Ernst Haeckel saw in it the answer to the "riddle of the universe"; Friedrich Nietzsche utilized the motif in the design of the *Ubermensch* theme; Hans Driesch and Henri Bergson employed it as the backdrop for the *entelechy* and *l'elan vital* roles in nature's drama; it appears in G. Stanley Hall's "physchic recapitulation" and Samuel Butler's recrudescent Lamarckian doctrines, only to disappear—and then reappear in Carl Jung's "racial unconscious"; Hegel's pantheistic romanticism posits the pattern of the *dialectic* as the carrier wave for the movement of God through history, while Karl Marx, inverting the meaning of the Hegelian pattern, translates the movement into the "laws" of Dialectical Materialism *(Diamat).* In the meantime, Lucien Levy-Bruhl's and James Mark Baldwin's postulated transition from the

primitive, pre-logical mentality to the mind of man as it functions logically according to the classical laws of thought finds its analogue in the three levels of explanation of Auguste Comte's form of positivism, these, in turn, to become the possible prototypes for the "levels of orientation" of Alfred Korzybski's system of *General Semantics;* while from the "social Darwinism" of William Graham Sumner (and not a few others) to the "evolutionary love" of Charles S. Peirce and the "creative intelligence" of John Dewey the chords of the evolutionary refrain in philosophy rise and fall—and rise again. Evidently the idea of "evolution" has itself undergone an evolution, so much so that it seems to enter into an onward moving crescendo of human thought to produce a cacophony of confusing sounds—a modernistic symphony which seemingly resolves no discords, achieves no final harmonic synthesis, and—thus far at least—seems to move to no obvious climax. If a mathematical sociologist were to study the evolution of the idea of evolution, he could not discern what are the "fundamentals" and what are the "overtones" of the Fourier series of mental evolution.

The theory of *emergent evolution*—momentarily at least—came closer than any other proposed integrative principle to providing a synthesizing nucleus for modern philosophy. This theory of levels, as it was sometimes called, in one form or another had the vigorous support of such outstanding thinkers as Wilhelm Wundt, Lester Ward, C. Lloyd Morgan, Samuel Alexander, Jan Smuts, Alfred North Whitehead, G. P. Conger, C. D. Broad, Roy Wood Sellars, and many others. But even this harmonious chord has been drowned out by the frenetic fortissimo of current intellectual disintegration. What budding promises of synthesis were emerging twenty-five years ago have been killed off by the chilling frosts of anti-speculative tendencies of the school of *Analysis* born in the climate of polar positivism of Ludwig Wittgenstein and the Vienna circle and currently putting the deep freeze on philosophy through the cold wave of the new "Oxford movement" hanging over England and certain parts of America.

The great virtue of the theory of emergent evolution—as some of us saw it two decades back—was well summarized by Professor E. G. Spaulding in his volume, *The New Rationalism* (1918, 444-450), in the following manner: "The properties of the whole are, at least some of them, new, and in just this respect *are a law unto themselves and in that sense free.* This does not mean that their specific principles of 'behavior' are not identical with those of the parts . . . . Freedom consists, therefore, of actions in accordance with the characteristics which subsist at a certain level of organization but do not exist at other (lower) levels, yet it is quite compatible with law and determination at this higher and at lower levels." When we refer to the "virtues" of the

theory of emergence we mean, of course, what Professor Spaulding obviously had in mind, namely, that the conception of two kinds of laws, laws of behavior *within* levels and laws *between* levels—*intraordinal* and *transordinal* laws, as C. D. Broad designated them—provided the basis for a reconciliation of determinism and freedom, mechanism and teleology. This compromise was clearly intended in the following passage, quoted from Professor William Morton Wheeler's little book, *Emergent Evolution and the Development of Societies.* As Wheeler states: "When our thinking tends to congeal into two conflicting interpretations we naturally either devote our days to showing why the one must be true and the other false, or we seek to escape from both by adopting a new position.

"The theory of Emergent Evolution; endeavors to avoid the 'nothing but' attitudes of *naturalism vs. supernaturalism, materialism vs. spiritualism, mechanism vs. vitalism, determinism vs. freedom,* etc., and opens up the way to a more consistent and more satisfying view of universal reality."

This was an excellent statement of a program. It marked out a hopeful approach to the resolution of some age-old conflicts in the overlapping fields of science, religion, and philosophy. But interests and emphases shift with the decades. Perhaps there are fads—even vagaries—in the field of philosophy. In any event, this synthesis at the moment is generally ignored. There is now widespread suspicion of what Bertrand Russell terms the "vague generalities" of the "system-maker's vanity." Nonetheless, there still remain those who are convinced that the enduring function of philosophy is to provide the integration of knowledge which Herbert Spencer labored so ardently to create through his project of philosophy as the "synthesis of the sciences." In a world where the accumulation of mountains of knowledge is constantly being accelerated, philosophical synthesis seems increasingly urgent if we are not to be overwhelmed by the sheer anarchy of factual data. As one looks at the situation today, it appears that one promising way to attain an orchestration of ideas is to explore the possibility of harmonizing the views of John Dewey and Alfred North Whitehead. We have space here merely to hint at what might be attempted.

John Dewey's philosophy is biological in its point of departure, but unlike other proliferations of evolutionary thought, Dewey's Instrumentalism is very revolutionary in its outcome. Knowledge is a part of nature because mental activity is man's manipulation of the environment to achieve "consummatory satisfactions," and thus the alleged "fixed structure of the mind"—the final refuge of non-progressivism in religion, education, and politics—is undermined by a movement of thought which is more unsettling to the established order than anything that current Existentialism is able to offer.

To see why this is so, consider the implications of Instrumentalism in two related areas: those of social ethics and of logic. Just as Dewey rejected the thesis of T. H. Huxley's *Evolution and Ethics,* based on the supposed opposition between cosmic processes and ethical processes, so Dewey similarly rejected Herbert Spencer's laissez-faire individualism according to which the interference of the social scientist in human affairs becomes an obstacle to understanding the social situation. At this point Dewey's thesis seems close to the Marxist view: the business of philosophy is not to "understand" the world in its eternal givenness, *but to transform it.* One can't understand without changing, recreating. Fortunately, Dewey outgrew the Hegelianism of his early period, so that, unlike Marx, who accepted the Hegelian pattern of conflict of opposites while perverting it for his own ulterior purposes, Dewey never faced the necessity of making Hegel "scientific" by translating the dialectical formula into a ritual for the messianic mission of communism. For Dewey, the road to democracy was thus always free from the "direct action" techniques of the Marxist "class struggle."

Nevertheless, for democratic Instrumentalism the problem still remains: in the process of refashioning human nature and society, where do we get our sense of direction for ongoing social evolution? The trouble with Dewey—according to Dewey's critics—is that while, like Protagoras of old, he teaches that *man is the measure of all things,* Dewey gives us only a rubber yardstick, since man is everlastingly on his way and never arriving at any final destination in this still-evolving world. In support of their assertion that Dewey's Instrumentalism ends up in a relativistic nihilism, critics will point to a more recent study, *Logic, The Theory of Inquiry,* where it appears that our fundamental modes of thinking, our operational processes, are in flux. If scientific method is still in process, where do we get the valid standards for our operational procedures? And what can be affirmed in the name of science as having what Dewey terms "warranted assertability?" Does it not appear that the outcome of Instrumentalism is a creeping skepticism far more destructive in its effects than any mere ethical or cultural relativism?

What is the remedy for this intellectual and social nihilism? Perhaps the basic trouble arises from the fact that Dewey's theory is a philosophy without a cosmology. If Dewey's biological-social Instrumentalism could be integrated into the kind of cosmology which Professor Whitehead's system so promisingly initiated, we might be on the way to a well-rounded world-view adequate to the needs of the new age of man. For example, Dewey might well utilize Whitehead's notion of a "cosmic epoch" as the answer to the riddle of the right norms in scientific methodology.

It seems that both Dewey and Whitehead, for rather different

reasons, should deny that Aristotle could have a theory of evolution. They should also deny that many so-called modern evolutionists really are evolutionists. Dewey, I surmise, would doubt whether we can have a satisfactory theory of evolution until we work out the implications of evolution for psychology, i.e., that mind is always in the making. Whitehead, on the other hand, might deny that it is possible to generate a satisfactory philosophy of evolution so long as it is built upon the misconception of the physical world as an assemblage of "particles," whether these be the "atoms" of Democritus or the "elementary particles" of certain current atomic and nuclear theories. Negatively, Whitehead's philosophy is a criticism of materialism in that the latter cannot provide a basis for a theory of evolution; positively, Whitehead's organismic physics supplies the foundation for a highly original cosmology. This new theory moves in the direction of an "organic mechanism." As this was first outlined in the influential book, *Science and the Modern World* (1925, Chapter VI and *passim),* we find—says Whitehead—that science is taking on a new aspect which is neither purely physical nor purely biological. Science is becoming the study of organisms. The primary units of nature are "events," not "particles." This "becoming" philosophy is developed in greater detail in Whitehead's later volume, *Process and Reality*.

In retrospect it seems that one outstanding merit of Professor Whitehead's theory of nature is that it places the philosophy of science on a new basis. As with Dewey's conceptions, Whitehead's cosmology is not only a solvent of old issues; it is also a center of crystallization for novel and more satisfying formulations. In this respect, both thinkers are looking in the same direction. But the thoughtful student asks, if both physics and psychology are still developing, if—more than that—the "entities" that both are studying are evolving, how can science achieve a synthesis which will have even temporary validity, not to mention ultimate finality? The answer is this: The fact that both "matter" and "mind" are evolving need not throw us into a debilitating skepticism. The discovery that the truths of science and philosophy undergo change and flow does not reduce our existing facets of knowledge to the status of driftwood in the restless tides of human opinion. There is a sense of direction in the ebb and flow of knowledge, just as there seems to be an upward thrust in the cosmic flow of energy; for, as Erwin Schrodinger puts it, "life feeds on negative entropy," to produce the "creative advance of nature"—to employ Whitehead's terminology.

Professor Julian Huxley has written of evolution as a "modern synthesis." But in the present stage of intellectual development every synthesis is incomplete. The modern temper makes room for the ceaseless search, a tireless movement toward distant

goals. And so, we recognize, the last chapter of the story of biological evolution has not yet been written, certainly not by man and perhaps not by nature.

At the present time, it appears that the more significant components of the progressing evolutionary synthesis are carrying us forward in two directions: on the one hand, we are looking backward in time and outward in space to explore the external or cosmic framework of biological evolution, and this carries us into the domain of what one investigator has termed "cosmecology"—the study of the dynamics of our solar system and the revolving galaxy of which it is a part. For a statement of the derivation of "cosmecology" and its meaning, see the article, "Cosmecology: A Theory of Evolution," by O. L. Reiser, *Journal of Heredity*, Vol. 28, 1937, 367-371. See also my volume, *The Integration of Knowledge*, 1958, Chapter XIII.

On the other hand, we are looking forward in time to the next steps in human biological and social evolution—the increasing conscious control of man's evolution, not merely in terms of a possible program of eugenic reforms but perhaps also along the lines of L. L. Whyte's thesis (or similar theories) concerning the "next development in man." Both lines of research are indicative of the possibilities inherent in the still unfolding story of the "influence of Darwin on philosophy."

Darwin himself seems to have made a place in his own thinking for the possibility that evolution is not yet through with human evolution. In the closing paragraph of the *Descent of Man*, Darwin wrote: "Man may be excused for feeling some pride at having risen, though not through his own exertions, to the very summit of the organic scale; and the fact of his having risen, instead of being placed there aboriginally, may give him hope for a still higher destiny in the distant future." In this passage Darwin seems to share some of the Victorian optimism which, in the case of Herbert Spencer and others, culminated in the identification of "evolution" and "progress." Today, after two world wars, we are not so naive as some post-Darwinian enthusiasts. Nevertheless, in spite of catastrophic setbacks, man is learning. Even now the biochemists who are studying the molecular structure of genes are telling us that the first long step toward the creation of living matter in test tubes hinges on the solution to the problem of finding the specific structure of nucleic acid, the "stuff of life" and its evolution. Once living matter is created, this will give the scientist a short cut for bypassing the long time-scale and thus yield some control over the processes of evolutionary change. It is even possible that the solution to these problems will provide a unique approach to improving the course of mankind on earth.

If the scientist can learn the secret of synthesizing a structure possessing genetic continuity while yet yielding the controllable

mutations which further evolution requires, the implications of such achievements are simply enormous. Man at long last will become the fabricator of his own further evolution—the conscious creation of the new humanity. The proper mood for this Promethean enterprise is one neither of "optimism" nor of "pessimism"—*operation humanity* is an awesome undertaking, one that requires reverence no less than wisdom.

HINDUISM AND THE IDEA OF EVOLUTION

Swami Nikhilananda

WHEN I WAS ASKED to write about the influence of Darwin's theory of evolution on India, I said that the influence was practically nil for the simple reason that the first English university was established in India just two years prior to the publication of *Origin of Species*. Even today a bare 2 per cent of Indians can read or write English. But I pointed out that a long time ago Hindu philosophers had formulated their own theories of evolution, which have for the past three thousand years profoundly influenced the thoughts of the Hindus. The present article has been written to give a brief survey of the ideas of evolution as discussed in some of the important philosophical systems of India. It should however be noted at the very outset that any comparison between the Western and the Indian idea of evolution will be both unfair and fruitless; for they have different premises, different methods, different aims and purposes, and different fields of investigation. Darwin and his followers were solely concerned with the evolution of physical forms and structures, whereas the Hindu philosophers discussed evolution from the standpoint of the soul. But Hindu thinkers, by an unprejudiced and respectful study of the Western theory of evolution, can benefit from it, as can Western thinkers by a study of the Eastern theories.

The idea of evolution is found in the Vedas, which date back to at least two thousand years before Christ. Later this idea was elaborated in various systems of Hindu philosophy. The conclusions arrived at are based upon not only scriptural statement, but reasoning and careful observation of facts according to the knowledge available at the time. The Hindu scriptures record the experiences of seers endowed with a spiritual insight which they developed through the disciplines of self-control, non-attachment, and concentration.

We read about evolution in the philosophy of the Upanishads, the Samkhya, and the *Yoga-sutras*. According to the Upanishads, which form the conclusion and the essence of the Vedas and are also the basis of the Vedanta philosophy, Atman, or the unchanging

spirit in the individual, and Brahman, or the unchanging spirit in the universe, are identical. This spirit or consciousness—eternal, homogeneous, attributeless, and self-existent—is the ultimate cause of all things. Our knowledge of its existence is based upon the direct experience of illumined souls, and also may be inferred from cosmology and psychology, which latter, according to Hinduism, is the science of the soul. From Brahman evolved the first individual, called Saguna Brahman, or Brahman endowed with the attributes of creation, preservation, and destruction. This Brahman, worshipped as the Personal God by various religions, is the direct cause of the universe and living beings. He is described as omniscient, omnipresent, compassionate. At this stage of evolution the diversity of the universe is not apparent. Saguna Brahman may be compared to the first sprout of a seed in which the future tree lies latent. Let us examine the meaning of evolution of Saguna Brahman from attributeless reality.

Vedanta philosophy speaks of attributeless reality as beyond time, space, and causality. It is not said to be the cause of the Saguna Brahman in the same way as the potter is the cause of the pot (dualism), or milk of curds (pantheism). The creation of Saguna Brahman is explained as an illusory superimposition such as one notices when the desert appears as the mirage, or a rope in semi-darkness as a snake. This superimposition does not change the nature of reality, as the apparent water of the mirage does not soak a single grain of sand in the desert. A name and a form are thus superimposed upon Brahman by maya, a power inherent in Brahman and inseparable from it, as the power to burn is inseparable from fire. The nature of maya is inscrutable to the finite mind, which is a later development of maya. We are told by scientists that a solid stone is nothing but a mass of electric charges. Nobody knows why or how the intangible electric charges appear as the solid stone. When science tells us that electric charges appear as a solid object, it is merely stating a fact of experience. Similarly, maya is a statement of fact.

Brahman in association with maya evolves Saguna Brahman, and the latter, as we shall presently see, the universe and living beings. According to Vedanta, maya is the material basis of creation; it is something positive. It is called positive because it is capable of evolving the tangible material universe. Though maya, in itself, does not possess the attributes of matter, yet it is capable of producing matter, just as molecules of hydrogen and oxygen, though they do not, in themselves, possess the attributes of quenching thirst or nourishing plants or becoming solid at a certain temperature, yet can produce water, which is endowed with these attributes. From maya evolve the concepts of time, space, and causality. Maya is said to consist of three gunas. The word *guna* is often translated as quality. But the

gunas are not in reality attributes of maya, as hardness is of a stone, or softness of butter; they are the components of maya, like the three strands of a rope. The three gunas are called sattva, rajas, and tamas. Sattva represents what is fine and light in nature, rajas what is energetic and active, and tamas what is coarse and heavy. These three characteristics are present in varying proportions in all things of the phenomenal world which are the effects of maya. The attributes of the effect are present in the cause. The threefold nature of maya explains the creation in its physical and psychic aspects. The presence of one guna could not account for the variegated universe; two gunas would cancel each other's effect. No phenomenal being, be he a god or a worm, is free from the gunas. The difference between one creature and another lies in the preponderance of one guna over the other two. Thus some beings preponderate in sattva, some in rajas, and some in tamas. Saguna Brahman, with the help of rajas, creates; with the help of sattva, preserves; and with the help of tamas, destroys the universe. Reality, or the attributeless Brahman, is beyond the gunas. Saguna Brahman is associated with the gunas, but is not controlled by them. The creature, however, comes under the influence of maya and becomes entangled in the world. Tamas binds a man with attachment to delusion, rajas with attachment to activity, and sattva with attachment to happiness. Sattva manifests itself as various spiritual virtues and shows the way to liberation of the soul from the prison-house of matter.

When the inexplicable power of maya begins to operate, the true nature of the attributeless Brahman becomes hidden, and there arises the condition of individuation, just as when the true nature of a rope is hidden by darkness there arises the possibility of its being mistaken for a snake, or a stick, or a fissure in the earth. The transcendental reality appears as the Personal God. The Bhagavad Gita states that God, from His lower nature, that is to say, maya, creates the material forms, and then endows them with life and intelligence by His higher nature, which is consciousness. Thus He is both efficient and material cause. The Upanishad gives the example of the spider, which from the standpoint of its silk is the material cause of the thread, and from its own standpoint the efficient cause. It should also be noted that God, or Saguna Brahman, and the attributeless reality are not essentially different. Maya, which makes the apparent difference, inheres in Brahman. When the reality remains inactive in its pure state it is called the attributeless Brahman, and when the same reality participates in the activities of creation, preservation, and destruction, it is called Saguna Brahman. Whether water is calm or choppy, it is the same water.

Saguna Brahman is sometimes called the Unmanifest, because He contains in a latent form the future diversity of creation.

Evolution or manifestation is periodical or cyclic; manifestation and non-manifestation alternate; there is no continuous progress in one direction only. The universe oscillates in both directions like a pendulum of a clock. The evolution of the universe is called the beginning of a cycle, and the involution, the termination of the cycle. The whole process is spontaneous, like a person's breathing out and breathing in. At the end of a cycle all the physical bodies resolve into maya, which is the undifferentiated substratum of matter, and all the individualized energy into prana, which is the cosmic energy; and both energy and matter remain in an indistinguishable form. At the beginning of the new cycle, the physical bodies separate out again, and the prana animates them. Evolution and involution are postulated on the basis of the indestructibility of matter and the conservation of energy. From the relative standpoint, the creation is without beginning or end. A cycle is initiated by the power or intelligence of God. According to Hindu thinkers, the present cycle commenced about three billion years ago. It appears from some of the Upanishads that all beings - superhuman, human, and subhuman - appear simultaneously at the beginning of a cycle. It is further stated in one of the Upanishads that Brahman first created a lump of matter which He shaped like a person. Next the person developed various organs and physical parts, which then became animated by the power of Brahman.

The first element to evolve from Saguna Brahman is akasa, which is usually translated as either, space, or sky. Akasa is the intangible material substance pervading the universe. Brahman associated with maya appears as akasa. From akasa evolves air (vayu); that is to say, Brahman associated with maya, appearing as akasa, further appears as air. From air evolves fire (agni); from fire, water (ap); from water, earth (prithivi). The principle of illusory superimposition is to be applied in the evolution of each element. The gunas, Sattva, rajas, and tamas, which are the components of maya, are transmitted at the time of evolution to the five elements, in accordance with the law that the nature of the cause determines that of the effect.

The five elements, thus evolved, are subtle and rudimentary. They are called subtle because they are imperceptible to the sense-organs and also because by themselves they are unable to produce gross objects. They are called rudimentary because each of these elements possesses its own characteristic alone. Thus the characteristic of subtle akasa is sound, of subtle air touch, of subtle fire color, of subtle water flavor and of subtle earth odor. The physical world can be grasped by the sense-organs in five ways only; that is why Hindu philosophers postulate only five elements.

Out of the subtle elements evolve two sets of organs and also

the subtle body. The inner organ consists of the intellect, the ego or I-consciousness, the mind, and the mind-stuff. The intellect is the discriminative faculty; the mind creates doubt and sees the pros and the cons in a given situation; the mind-stuff is the store-house of the tendencies created by past actions; and the ego makes the spirit identify itself with the body. The outer organs consist of the five organs of perception and the five organs of action (hand, feet, vocal organ, and the organs of reproduction and evacuation). Besides the organs, there is also the prana, or life-breath, which is a manifestation of the cosmic energy and which functions in a body in five different ways: in breathing, in ejecting unassimilated food and drink, in carrying sensation to different parts of the body, in nourishing the whole body by food digested in the stomach, and in helping the soul to leave the body at the time of death. This energy is present even in the very smallest particle of matter, and when released can exhibit unbelievable power. All these are products of maya and physical in nature. They function only when activated by the omnipresent Brahman, or consciousness. The finer the organ, the more it reflects the intelligence of Brahman. A preponderance of sattva, which has the attribute of transparency and light, makes an object fine. Thus the intellect, containing a large proportion of sattva, reflects more of Brahman than the other organs. The reflection of Brahman in the intellect is called the jiva, or individual soul, which, when identified with a body, becomes an embodied creature.

By an organ the Hindu philosopher means both the outer organ and its subtle counterpart. Thus, the organ of seeing is not the visible eye, but an intangible organ made of the subtle elements. But even the subtle organ cannot perform its function of seeing, because it is inert. Only when controlled by Brahman can it see. A particular aspect of Brahman controls a particular organ and is called a god, or deity. Thus the visible eye has a subtle counterpart and also a controlling deity, which is identified with the sun. The deity controlling the subtle organ of touch is identified with air; and so on. The sun, air, etc. are regarded as channels for the manifestation of Brahman. Thus Vedanta philosophy presents, in poetic language, a seamless continuity between physical, psychic, and so-called supernatural entities. The five organs of action, the five organs of perception, and the five pranas, together with the mind and intellect, constitute the subtle body, with which the soul migrates from one life to another.

From the five subtle elements evolve the five gross elements. Unlike the former, the gross elements are compounds. They are produced by the combination of the subtle elements in a certain proportion, and each gross element contains something of the other four. The gross elements are the bricks of the visible universe, of the different physical bodies, and of the food and drink which sustain living beings.

The individual soul, identified with a physical body, is endowed with the power of knowing, feeling, and willing. It is the agent of action and the reaper of its fruit. It is a combination of matter and spirit. During the successive stages of evolution, it remains oblivious of its spiritual nature, which, however, is not destroyed. The same spirit shines with undiminished light in the amoeba as in a god. Since the very moment of the identification of the creature with matter, its inner spirit has been trying to remanifest its true nature. For this purpose it assumes various bodies to create a suitable vehicle. According to the Hindu doctrine of rebirth, the soul can assume a lower or a higher body according to its desires and the impressions of its past actions. But all living beings will ultimately attain perfection. The struggle at the subhuman level is carried on through instinct, on the human level through reason, and on the superhuman level through intuition, which is a refined form of reason cultivated by means of the spiritual disciplines prescribed by the higher religions. At the irresistible urging of spirit, the soul assumes different bodies—from the body of a stone or a tree to that of a celestial being—and discards them all as unsuited for the complete manifestation of its transcendental nature. This is the philosophical meaning of the Hindu doctrine of reincarnation. When the soul becomes detached from all bodies it becomes free from the bondage of matter. Then the individual creature realizes its oneness with the atrributeless Godhead. This liberation of the soul from the prison-house of matter is the ultimate goal of evolution.

With regard to the above description, it should be remembered that Hindu philosophers regard the knowledge of Brahman or Atman as the ultimate goal of philosophical inquiry. In Hindu thought, the various species of living beings are so many vehicles for the soul's expression; they are not to be regarded simply as products of a mechanical process. The purpose of evolution is to enable the soul to realize its spiritual nature; otherwise life on earth becomes meaningless and futile. Even the pursuit of art, science, and philosophy for the mere sake of knowledge does not remove the central hollowness of a life lived in a universe composed of material particles and controlled by physical laws. Apart from Brahman the universe is insignificant and irrelevant. Nay, the material universe, according to the testimony of mystics, ceases to exist in the deepest spiritual experience. All material achievements on earth are transitory. To realize man's real nature is much more important than to understand the nature of the universe for its own sake or for the enjoyment of material happiness. The interpretation of the universe must lead to the knowledge of Brahman. By this test the Hindu speculations about evolution are relevant.

Let us now discuss the idea of evolution according to the

Samkhya philosophy founded by Kapila, an ancient philosopher mentioned in later Hindu writings. The earliest extant book on classical Samkhya is the *Samkhya Karika,* written about 600 A.D. In spite of many similarities with Vedanta, Samkhya differs from the latter in some important respects. It traces the origin of physical objects directly to primordial matter and regards the process of evolution as real, not illusory. It is dualistic, admitting the independent reality of both matter and consciousness, and besides, of twenty-three other categories or cosmic principles.

The following are some of the postulates accepted by Samkhya philosophers:

(a) Whatever is always exists; whatever is not never exists.
(b) Change is not possible without admitting the existence of something that changes.
(c) An effect is not essentially different from its material cause.
(d) Diversity can eventually be traced to three sources, which are interdependent.
(e) The characteristic of matter is perpetual motion.
(f) Both matter and mind are independent realities: neither is mind derived from matter, nor is matter derived from mind.

According to the Samkhya philosophy there is a plurality of souls, or purushas - a conclusion based upon the multiplicity of living creatures as seen in the creation. These souls, which are centers of consciousness, are incorporeal but inactive. The first cause of the universe is prakriti, or nature, which produces all physical entities. The latter include both matter and energy. The Samkhya philosophy does not admit a Creator-God, because according to it there is no proof of His existence. The purusha is outside prakriti, but time and space exist within it. Matter does not exist in time and space. As an effect is non-different from its material cause, the nature of prakriti is deduced from that of tangible objects. As all such objects consist of the three gunas already described, prakriti must also have them as its component parts. Each of the three gunas is manifold, for each one of them is associated with the other two in varying proportions; thus one sees infinite variety in the visible nature. The gunas form the substratum of evolution. They persist when their effects come into existence and when they disappear. The dissolution of the universe is described as the state when all the works of the gunas remain latent. Their activity precipitates evolution. But prakriti, even in the state of dissolution, is not altogether inactive; instead of producing unlike forms, it reproduces itself. If prakriti once stopped its activities, no new creation could take place. Prakriti is lifeless; hence it cannot move by itself. Its motion is explained by the presence of the conscious purusha, which, however, does not actively participate in evolution. The Samkhya philosophers give the example of a magnet and iron-filings.

Though prakriti is non-intelligent, yet evolution serves a purpose, which is the emancipation of the soul. But only the individual soul is emancipated, and not the whole species. Like the Vedanta theory, the Samkhya theory of evolution accepts the indestructibility of matter and the conservation of energy. The evolution of a form is only the manifestation of what already exists. A pot is produced from existing clay. Likewise destruction means only a change of form, not total annihilation. When a pot is destroyed, it reverts to clay.

There are two arguments which support the reality of prakriti. The first, already referred to, is that nothing new can come into existence. The totality of the visible universe was given in the very beginning. The latent or implicit form is called the cause, and the visible or explicit form, the effect. The example of the clay and pot has just been given. The ultimate implicit state is called prakriti. The second argument is that the finite implies the infinite, that is to say, the finite transcends itself. The finite is not pervasive; it cannot be supported by itself, but is pervaded by its subtle counterpart; the latter is pervaded by another principle. Proceeding backwards in this manner we arrive at prakriti, which is all-pervasive and self-sustaining. If we seek a pervader of prakriti we shall get only another prakriti. Thus prakriti is the ultimate cause of material forms.

Now let us consider the different stages of evolution. From prakriti evolves mahat or buddhi, that is to say intellect, which is illumined by the purusha and thus acquires consciousness, the characteristic of the purusha. It predominates in sattra and is a sort of vague general consciousness, which is unable to distinguish between subject and object. The next principle to evolve is ahamkara, or I-consciousness, that is to say, the empirical self, which preponderates in rajas. At this stage consciousness becomes self-conscious and is able to perceive an object. The empirical self is endowed with the attributes of knowing, willing, and feeling. These three principles—prakriti, mahat, and ahamkara—are postulated on the authority of the Samkhya seers. Ahamkara, or the empirical self, in its turn evolves into four principles, depending upon the preponderance of one guna or another. It should, however, be remembered that rajas is always the accessory cause of evolution on account of the fact that its main trait is energy. By the preponderance of sattva the empirical self evolves the five organs of perception, by the preponderance of rajas the five organs of action, and by the preponderance of tamas the five subtle rudimentary elements. The organs are evolved for the acquiring of experience by the empirical self. The fourth principle to evolve from the empirical self is the manas, or mind, which is the direct instrument for connecting itself with the organs of perception and action. What

is perceived as mere sensations by the senses is connected, interpreted, generalized, and formed into concepts by the mind.

From the subtle elements evolve the gross elements of akasa, air, fire, water, and earth. They are the objects through the experience of which the empirical self ultimately obtains liberation from prakriti. From rudimentary akasa (subtle sound) evolves gross akasa, with sound as its manifest attribute; from rudimentary akasa and rudimentary air combined, gross air, which is therefore endowed with the attributes of sound and touch; from these two rudimentary elements and rudimentary fire, gross fire, which has the attributes of sound, touch, and color; from these three rudimentary elements and rudimentary water, gross water, which has the attributes of sound, touch, color, and flavor; and lastly from these four rudimentary elements and rudimentary earth evolves gross earth, which has all the five attributes of sound, touch, color, flavor, and odor. As the gross elements evolve they become more and more concrete. Each element has a manifold nature, and consists of finite and disparate particles. Out of these particles is formed the tangible universe, which is the field of experience for the embodied soul. The evolution just described may be called primary. There is also the secondary evolution by which a caterpillar turns into a butterfly, and bones and trees into fossils.

All through the process of evolution, as already stated, prakriti alone is active; the sentient purusha does not directly participate. The purusha is the experient without being the doer. By its mere presence the purusha guides evolution. This dual function of the purusha and prakriti is illustrated by the example of a lame person who can see and a blind person who can walk. The former wants to reach a certain destination but cannot without the help of the blind person. He climbs upon the shoulders of the blind man and guides him along the road while the latter walks. The lame man is the purusha, and the blind man, prakriti.

The existence of the purusha is deduced from several arguments. First, an object always implies a subject. The physical universe is insentient and needs a sentient entity to experience it. Second, the very concept of a prakriti complex in nature implies something which is simple; and that is the purusha. Third, a design is found in nature. This design, however, need not posit a conscious designer. As already stated, the Samkhya philosophy denies the existence of a God who is the designer of the universe. But someone should be benefited by this design; and the being that is benefited by it is the empirical soul. The soul gains various experiences from the world evolved from prakriti, and these experiences create detachment, which leads to its ultimate liberation. This is explained by the example of a dancing-girl who displays her physical charms before a group of spectators. One

of these falls in love with her, courts her, and enjoys her company. When he is satiated with her, she, with a smile, gives him up and turns to another man. The disillusioned man is liberated. Thus she goes on furnishing experiences to one person after another, and giving to each liberation. The activity of prakriti has no beginning or end. The isolation of the purusha from prakriti is called liberation (kaivalyam). Fourth, there is a universal longing for release, which implies someone who seeks it; and that is the purusha. Prakriti evolves for the purpose of bringing about its release, which again is not possible without previous experiences on the purusha's part. Since it is impossible for the soul to experience everything in one life, Hindu philosophers postulate the rebirth of the soul, which has already been mentioned. It may be noted, however, that a soul at the time of its birth is endowed with the tendencies and desires of the previous one. They form a sort of blue-print which guides the general trend of its present life. Heredity determines the physical characteristics, and environment helps it to give expression to its inherited mental tendencies. A soul, by the law of affinity, selects parents and environment to serve its purpose. Neither cellular transmission nor environment nor both of these can completely explain a man's thoughts and actions.

The Yoga philosophy formulated by Patanjali is based upon Samkhya, though it differs from the latter in one important aspect, in that it makes room for God, who is described as a special person (purusha) untouched by misery, desire, actions, and their results, who is unlimited by time, and in whom knowledge which in others lies only as a germ becomes infinite. God, in Yoga, differs from Saguna Brahman in Vedanta. The former is outside the universe, wheras the latter is both in the individual and in the universe. According to Yoga, God is not directly responsible for the evolution of prakriti, yet His presence gives the impetus. Through His mercy a man does good and refrains from evil. This accelerates the process of evolution. But a yogi, even without belief in God, can attain the ultimate goal by means of various disciplines prescribed by the Yoga scriptures.

There are two important texts in Patanjali's *Yoga-sutras* which have a direct bearing upon evolution. According to one, a creature evolves into another by the filling in of nature. An important implication of Patanjali's theory is the fact that the perfection whose attainment is the goal of evolution is already present in a creature, but is barred off by certain obstacles. When these are removed the perfection rushes in of itself. The illustration is given of a field in need of water. The water, which is in a canal, is held back by gates; as soon as the farmer removes the obstruction, the water for irrigating the field flows in. The other test states that good and bad deeds are not the direct cause of

evolution, but simply act as breakers of the barriers. As good deeds prevail, lower bodies are transformed into higher. All the materials of evolution exist in nature; a person can choose what suits his purpose. Some persons unwilling to waste time in repeated births and deaths, change bodies in order to facilitate higher evolution in one lifetime.

It may be interesting to narrate a Hindu myth which speaks of God's assuming different bodies to help living creatures at different levels of evolution in the attainment of their goal. Thus when the world contained nothing but water and was filled with sea-creatures, God became incarnated as a fish. When solid earth appeared and the amphibious creatures evolved, God assumed the form of a turtle. Then God embodied Himself, in succession, as a creature half animal and half man, a hunter, a man conscious of family and social duties, a compassionate man, and a perfect man.

The Hindu theories of evolution, as briefly outlined in this article, will appear to Western scientists mystical and speculative. But Hindu philosophers claim that they are based upon experience, observation of facts, and reasoning. The main trend of the reasoning is, no doubt, to proceed from the general to the particular, but the inductive element is not absent. Intuition, which is a higher state of reasoning, has played an important part in the formulation of Hindu philosophical doctrine. Reason based upon sense-perception helped the Hindu philosophers as far as it could, then bowed itself out, yielding place to intuition.

To sum up the Hindu idea of evolution: Evolution takes place in the realm of matter. But matter is not in itself a self-creating, self-preserving, and self-destroying substance. It needs the direct or indirect help of a conscious principle; without such a principle the entire process of evolution cannot be adequately explained. Evolution presupposes involution. If an amoeba evolves into a highly developed man, then that man must have been involved in the amoeba. If consciousness or intelligence evolves from inert matter, it must be implicit in matter. The very concepts of "struggle for existence" and "adaptation to the environment" suggest the presence of intelligence, whether instinctive or highly developed. Hinduism does not deny the place of competition or adaptation in the evolution of creatures. But according to it, these methods operate only on certain levels. On other levels, spiritual disciplines such as co-operation, self-denial, purity, compassion, and love give the impetus.

There are certain fundamental differences between the Indian and the Western ideas of evolution, and also between their implications. First, Hinduism does not accept the view that evolution is entirely a natural process, or that man is the latest dominant type to be produced by evolution. Evolution, on the contrary, is

directly or indirectly influenced by a power outside nature. Second, according to Vedanta, the first created being was a person, only one step removed from the Creator. Third, no one has observed the emergence of life from non-living matter. The scientist has not been able to produce in his laboratory life from non-life or consciousness from unconscious matter. Fourth, Hindu philosophers do not accept the idea of general progress implied in the Western concept of evolution. The sum total of good and evil, pain and pleasure, always remains the same. We live in a world of change. But a person can take advantage of his experiences, no matter at what particular time he lives, and attain liberation.

The idea of evolution formulated by Darwin is a landmark in Western thought and has revolutionized many of its aspects. Western science and philosophy are revealing the nature of the physical universe and man's place in it. This knowledge has mitigated many of the evils of his physical life. It has also disturbed many dogmas of the traditional religions in the West. The Hindu idea of evolution emphasizes the spiritual nature of creation. A Hindu believes that both man and the universe, if investigated by reason alone, will remain a mystery. Reason can never give finality: one conclusion of reason is superseded or negated by another. Buddha refused to explain by reason the nature of God and creation, but pointed out that through the practice of spiritual disciplines a man can overcome suffering and enjoy peace and freedom. This, after all, is the aspiration of all rational beings. The Hindu scriptures speak of the need of cultivating the knowledge of both science and super-science: with the help of the former one conquers physical limitations, and with the help of the latter one enjoys immortality or freedom.

It may be rightly contended that the Hindu ideas of evolution, as far as an ordinary person is concerned, belong to the realm of speculation, lacking as they do experimental proof. The various steps of evolution they describe cannot be demonstrated in a laboratory by the scientific method. One can raise legitimate objections about certain of the concepts of the Vedanta and Samkhya philosophies.

The scientific method of the West, too, a Hindu may rightly contend, has its limitations. First, in any scientific investigation, the scientist is conditioned by his methods and instruments. Second, scientific classification gives valuable information, but it does not include all things in the subject classified. Much of the deeper reality—including such factors as goodness, beauty, and the soul—is left out. Third, the specialized sciences deal only with parts and thus do not discover the qualities which are present in wholes. Fourth, there are many interpretations of a thing, a person, or an event, each of which may be true as far as it goes.

Scientific investigation provides only one such interpretation. Therefore its findings are incomplete and inadequate. Fifth, when one considers the process of evolutionary development, one finds that the later stages are as important as the earlier stages and tell as much about the process. One of the fallacies of science is that it tends to emphasize the earlier development. Sixth, the specialized sciences are dependent upon man's sense-organs and upon his general mental equipment. There is a tendency to see what we are trained to see or expect to see. After the sensations are received through the sense-organs or through instruments, we have to employ inference or generalization. Thus the "standpoint of the observer" is receiving more and more attention in the field of scientific knowledge. A scientist, therefore, is limited by his finite mind and cannot grasp the entire process of evolution: its dim past and its far-off future. Lastly, when the physical sciences give only a materialistic and mechanistic interpretation of life they make it both futile and purposeless. The universe, too, becomes indifferent or even unfriendly to man's aspiration. Moral and other values grow increasingly relativistic, our appetites and aversions becoming their determinants. Scientism, if not corrected by spiritual concepts, is fraught with serious consequences for both individuals and the whole earth.

Notwithstanding these limitations, the Western sciences, besides achieving much in the realm of men's physical welfare, have destroyed many superstitions of the human mind, given natural explanations of events for which supernatural explanations are unwarranted, and, in general, added immensely to man's knowledge of the universe and of himself.

As indicated at the beginning of this paper, both Hindu and Western thinkers can learn from each other regarding the idea of evolution. Modern Hindu thinkers will certainly benefit by supplementing their own theories with the verifiable discoveries of Western scientists regarding the evolution of the forms and structures of living creatures. And Western thinkers, too, can add depth and significance to their own idea of evolution by incorporating in it the spiritual urge and the goal of the evolutionary process as discussed in Hindu philosophy. Perhaps, in the course of time, a master mind will be born who will combine both the Hindu and the Western ideas of evolution, and thus be able to give a complete history of man from his first wandering into the maze of the phenomenal world to his ultimate emergence as a free soul. And perhaps he will have to use both the scientific method of the West and the intuitive method of the Indian; for both knowledge and wisdom will play important parts in the solution of the great mystery.

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